CORRES. CONTROL
OUTGOING LTR NO.

DOE ORDER #

05 RF 00479

| DIST. | LTR | ENC |
|---|---|---|
| BERARDINI, J. | X | |
| BRAILSFORD, M.D | | |
| FERRERA, D.W. | X | |
| FERRI, M.S. | | |
| FULTON, J.C. | | |
| GIACOMINI, J. | | |
| HALL, L. | | |
| MARTINEZ, L.A. | | |
| PARKER, A.M. | | |
| POWERS, K. | | |
| SCOTT, G.K. | | |
| SHELTON, D.C. | X | |
| SPEARS, M.S. | | |
| TRICE, K.D. | | |
| VOORHEIS, G.M. | | |
| WIEMELT, K.L. | X | X |
| THORNBURG, AMY | X | |
| Primrose, A | X | |
| COR. CONTROL | X | X |
| ADMN. RECORD | X | X |
| WASTE REC. CTR. | | |
| TRAFFIC | | |
| PATS/130 | | |
| CLASSIFICATION: | | |
| UCNI | | |
| UNCLASSIFIED | | |
| CONFIDENTIAL | | |
| SECRET | | |

AUTHORIZED CLASSIFIER SIGNATURE
Exemption – CEX-105-01

Date

IN REPLY TO RFP CC NO:

ACTION ITEM STATUS
☐ PARTIAL/OPEN
☐ CLOSED

LTR APPROVALS:

ORIG & TYPIST INITIALS

KAISER•HILL
COMPANY

May 16, 2005

04-RF-00479

Mr. Joseph A. Legare, Director
Project Management Division
DOE, RFPO

TRANSMITTAL OF A COPY OF THE GROUNDWATER PLUME TREATMENT SYSTEMS OPERATION AND MAINTENANCE (O&M) MANUAL AND AN ADDITIONAL COPY OF THE TREATMENT SYSTEM DRAWINGS – KLW-035-05

Enclosed is a copy of the Groundwater Plume Treatment Systems O&M Manual and an additional copy of the Treatment System Drawings from the manual for your files.

If you have any questions, please contact me at extension 9883.

Robert N. Davis for
Karen Wiemelt
Manager, Environmental Restoration Programs

KW:dm

Orig and 1 cc – Joseph Legare
cc: Scott Surovchak

Enclosures:
As Stated

RECEIVED
MAY 17 2005

ADMIN RECORD

# Groundwater Plume Treatment Systems Operation and Maintenance Manual

## Table of Contents



**Tables**



**Appendices**



2

# 1 PURPOSE

This operations and maintenance manual provides the steps for routine operations and maintenance of the Solar Ponds Plume Treatment System (SPPTS), the Mound Site Plume Treatment System (MSPTS), and the East Trenches Plume Treatment System (ETPTS). In addition, this document serves as a guide for media replacement at all three treatment systems.

# 2 SCOPE AND APPLICABILITY

This document contains instructions for the operation and maintenance of the SPPTS, MSPTS, and ETPTS and is applicable to all Field Project Managers and workers who routinely work on these systems.

The groundwater treatment systems at the Site are designed to treat contaminated groundwater containing volatile organic compounds (VOCs), and/or elevated nitrates and radionuclides.

All three systems consist of a groundwater collection trench with a collection sump that feeds the groundwater to the treatment cells. Under normal operations, the treatment cells are configured so that water flows through the cells in series for treatment, and then to the metering manholes for release into an infiltration gallery. Appendix A shows as-built drawings of the three groundwater plume treatment systems. Appendix B has manufacturer's operation, maintenance, and specification information for the SPPTS solar pump system.

# 3 ROUTINE SURVEILLANCES AND MAINTENANCE

Routine surveillance and maintenance shall be performed as described in Table 1 below. Appendix C contains the checklist used to document routine operations.

For all three systems, the effectiveness of the treatment cells is influenced by the permeability of the media. The groundwater flowing through the treatment cells will cause surface crusting that periodically must be broken up to ensure an even flow across the entire surface of the treatment cell. Therefore, the systems must be routinely inspected and maintained to ensure continued flow and treatment.

**Table 1 - Routine Surveillance and Maintenance of Treatment Systems**

| Activity | Frequency | MSPTS | ETPTS | SPPTS |
|---|---|---|---|---|
| Check Water Levels in Treatment Cells or Collection Sump (Section 3.1 or 3.9.1) | Monthly | ✔ | ✔ | ✔ |
| Check Flow Rates/Flow Meter Flume (Section 3.2) | Twice monthly | ✔ | ✔ | ✔ |
| Check Valves and Piping (Section 3.3) | Biannually | ✔ | ✔ | ✔ |
| Clean Effluent Lines (Section 3.4) | Annually | ✔ | ✔ | |
| Routine Raking/Puncturing of Pea Gravel/Iron Mixture (Sections 3.5 and 3.6) | Monthly | ✔ | ✔ | |
| Replacement of Pea Gravel/Iron Mixture (Sections 3.7 and 3.8) | Annually | ✔ | ✔ | |
| Check Solar Pump, Panels and Charging System (Section 3.9.2) | Monthly | | | ✔ |

Table 2 gives the ranges for water levels in the treatment cells as well as the anticipated flow rates for normal operations. All of the systems can show higher than normal flow rates if there was a recent heavy

3

precipitation event or if there is an obstruction in the flow meter flume. Reported flow rates must be corrected for this when discovered.

**Table 2 – Typical Operating Range for Depth to Water in Treatment Cells and Flow Rate**

| Operating Parameters | Minimum | Maximum |
|---|---|---|
| **Depth to Water in Treatment Cells (in feet from the treatment cell doors)** | | |
| Mound Site Plume Treatment System | 4.2 | 4.7 |
| East Trenches Plume Treatment System | 4.7 | 5.2 |
| **Treatment System Flow Rate (GPM)** | | |
| Mound Site Plume Treatment System | 0 | 5 |
| East Trenches Plume Treatment System | 0 | 20 |
| Solar Ponds Plume Treatment System | 0 | 10 |

Note: Depth to water in the Solar Ponds Plume Treatment System cannot be measured because the treatment cells are not accessible

## 3.1 Monitoring of Water Levels in Treatment Cells

Following are the steps for measuring water levels in the treatment cells. These steps do not require entry into the treatment cells. SPPTS collection trench water level monitoring is detailed in Section 3.9.1.

1. Open the doors on the treatment cells and allow to ventilate for a minimum of five minutes.
2. Using a measuring tape or similar calibrated measuring device, measure the water level in the treatment cell from the treatment cell doors.
3. Close doors on the treatment cells.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

4. Record observations on the Routine Operations Checklist (Appendix C).

## 3.2 Inspection and Maintenance of Flow Meters and Flumes

The flow meters on all three treatment systems are similar to those used by ESS Water Programs Group. Flow meters shall be calibrated per the instruction manuals. Instructions will be provided in the O&M manuals for monitoring.

Following are the steps for flow meter and flume inspection and maintenance. These steps do not require entry into the treatment cells.

1. Open the cover on the metering manhole and allow to ventilate for a minimum of five minutes.
2. Inspect the condition of the flume from the outside of the metering manhole.
3. Remove any obstructions in the flume using a wooden pole or similar implement.
4. Close cover on the metering manhole.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

4

5. Record observations on the Routine Operations Checklist (Appendix C).

**If** the above cannot be performed satisfactorily without entry into the metering manhole, **then** enter the metering manhole.

Follow requirements for non-permit required confined space entry. The metering manhole monitors treated groundwater; therefore, there is low potential for harmful gases to be present in the system. Low levels of carbon monoxide have been seen in the past at these locations, primarily the ETPTS. Therefore, monitoring the atmosphere prior to entry is recommended to verify that it is safe to enter.

1. Open the cover on the metering manhole and allow it to ventilate for a minimum of five minutes.
2. Enter manhole using manufacturer's installed ladder.
3. Clean out flume and remove debris as necessary.
4. Close cover on the metering manhole.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

5. Dispose debris as sanitary waste.
6. Record observations on the Routine Operations Checklist (Appendix C).

**If** obstruction persists, **then** check for problems with valves and piping (Section 3.3).

## 3.3 Inspection of Valves and Piping

During normal operations, treatment cells shall be plumbed so that these operate in series. Normal valve positions are provided in Appendix A.

A valve key is provided at each treatment system for opening and closing these valves.

Perform the following steps:

1. Verify that valves are in the appropriate position for serial flow
2. Verify that water is flowing through the metering manhole
3. Verify that water is flowing out of the effluent piping
4. Make sure all doors are closed and that there is no means for outside air to enter the system.
5. Record observations on the Routine Operations Checklist (Appendix C).

**If** valves are not in the appropriate positions, **then** immediately inform management. At management's direction, return valves to normal positions.

**If** water is not flowing through metering manhole, **then** check for and clear obstructions as described in Section 3.2. **If** flow is not restored, **then** immediately inform management.

**If** water is not flowing through effluent pipeline, **then** check for and clear obstructions as described in Section 3.4. **If** flow is not restored, **then** immediately inform management.

**Note – During drought and low flow periods, water may not be observed in the metering manhole or effluent piping.**

## 3.4 Clearing of Effluent Piping (MSPTS and ETPTS)

The effluent piping discharges to the hillside below the metering manholes. The effluent piping may plug with iron bacteria or debris. This is cleared as follows.

Assemble the following tools and equipment as required:

- Shovel
- Powered plumber's snake at least 50 feet long (currently available on Site)
- Generator to power snake

Perform the following steps:

1. Clear any accumulated mud and debris from the effluent piping outfall.
2. Re-establish drainage away from the effluent piping outfall as necessary.
3. Following the operator's manual for the plumber's snake, clear the line to the metering manhole.

**Note – Post a watch at the metering manhole to watch for and keep the plumber's snake from entering flume and potentially damaging flow meter components.**

4. As snake is retracted, rinse off and dispose of residue in place.
5. Make sure all doors are closed and that system is isolated form outside air.

## 3.5 Routine Media Maintenance (MSPTS and ETPTS Only)

Following are the basic treatment cell maintenance steps. These steps do not require entry into the treatment cells.

1. Open the access doors and allow the treatment cell to ventilate for a minimum of five minutes.
2. Inspect the condition of the media from above the treatment cell. Report observations in the maintenance log or on the Routine Operations Checklist (Appendix C).
3. Break up crust by raking surface as required with a long handled, standard 4-tine garden cultivator rake, scaling bar or equivalent tools. The gravel should also be punctured 10-15 times with a digging or scaling bar in different locations to release trapped gases that might have accumulated in the beds.
4. If surface is too hard to rake or break up, notify management.
5. After breaking up any iron crust, regrade the media surface with the back of the rake or a similar tool. Be sure that all the media is submerged.
6. Rinse tools with clean water and discharge the water to the treatment cell. Close the treatment cell doors.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

7. Record all actions on the Appendix C checklist.

**If** the above cannot be performed satisfactorily without entry into the treatment cells, **then** proceed to Section 3.6.

## 3.6 Routine Media Maintenance Requiring Treatment Cell Entry (MSPTS and ETPTS Only)

Following are maintenance activities that require entry into the treatment cells such as breaking up crust in the gravel and iron layers.

**Note – If entry into any of the system components is required, non-permit required confined space entry requirements apply.**

Follow requirements for non-permit required confined space entry and obtain a ladder permit as required by Standing Order 83. The Site's Confined Space Entry procedure (MAN-072-OS&IH Manual, Chapter 21) shall be followed for any entry into the treatment cells, sump or metering manhole.

It is likely that hydrogen is present in the system and also possibly hydrogen sulfide, carbon monoxide, ethane and/or methane. In addition, there likely are low concentrations of volatile organic compounds in the water. These hazards shall be addressed prior to entry. Safety personnel may require use of a photoionization detector and/or a combustible gas indicator for entry.

Assemble the following tools and equipment as required:

- Aluminum or fiberglass extension ladder with an extended length of at least 10 feet.
- Long-handled shovels
- A pick or Pulaski tool
- Standard garden cultivator rake, lute or scaling bar
- Air compressor and tools for breaking up crust if hand tools are not sufficient
- Additional equipment required for a confined space entry

Perform the following steps

1. Open the access doors and allow the treatment cell to ventilate for a minimum of five minutes.
2. Measure and record depths to the top of the water and top of the media on the Appendix C checklist.
3. Place the ladder into the treatment cell and tie it off securely.
4. Enter treatment cell and inspect media for formation and accumulation of precipitates and formation of iron crust.
5. Break up iron crust and disposition as directed by management. This is expected to remain in the cell.
6. After breaking up any iron crust, re-grade the media surface with the rake or lute. Be sure that all the media is submerged. **If** media is not submerged, **then** notify management immediately.
7. Remove the ladder, rinse tools with clean water and discharge the water to the treatment cell. Close the treatment cell doors.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

8. Record all activities on the routine operations checklist (Appendix C).

**If** the treatment cell beds are not draining after breaking up the crust, **then** media replacement is probably required as described in Sections 3.7 and 3.8. Notify management immediately.

## 3.7 Partial Iron Media Replacement at the MSPTS or ETPTS

**Note – If entry into any of the system components is required, non-permit required confined space entry requirements apply.**

These steps may be used for partial bed replacement including replacement of just the gravel/iron layer or just the upper portion of the gravel/iron layer as needed. Based on the depth of crusting in the media, determine the amount of zero valent iron and gravel/iron mixture that requires replacement. Table 3 shows the approximate volumes of gravel/iron mixture in the treatment cells. Details of these calculations are found in Appendix D. The volume of iron is not provided as it is based on the amount of iron requiring replacement. The zero-valent iron specifications are found in Appendix E.

**Table 3. Depths, Thickness, and Volume of Treatment Cell Media**

| Parameter | ETPTS | MPTS |
|---|---|---|
| Outside Diameter (feet) | 11.50 | 9.83 |
| Inside Diameter (feet) | 11.33 | 9.67 |
| Inside Radius (feet) | 5.67 | 4.83 |
| Cross-Sectional Area (square feet) | 100.9 | 73.4 |
| Depth to Water from Treatment Cell Doors (feet) | 5 | 4.57 |
| Groundwater Head over Gravel Layer (feet) | 1 | 1 |
| Gravel Layer Thickness (feet) | 0.5 | 0.5 |
| Depth to Top of Iron from Treatment Cell Doors (feet) | 6.5 | 6.07 |
| Depth to Top of Gravel from Treatment Cell Doors (feet) | 6 | 5.57 |
| Volume of Gravel Layer (cubic feet) | 50.4 | 36.7 |
| Volume of Iron (cu ft) in Gravel/Iron Mixture | 5.60 | 4.08 |
| Drainage Layer Thickness (feet) | 0.9 | 1.0 |

**If** total iron replacement is required, **then** the vertical length of each treatment cell shall be measured to calculate iron volume.

Follow requirements for non-permit required confined space entry and obtain a ladder permit as required by Standing Order 83. The Site's Confined Space Entry procedure (MAN-072-OS&IH Manual, Chapter 21) shall be followed for any entry into the treatment cells, sump or metering manhole. It is likely that hydrogen is present in the system and also possibly hydrogen sulfide, carbon monoxide, ethane and/or methane. In addition, there likely are low concentrations of volatile organic compounds in the water. These hazards shall be addressed prior to entry. Safety personnel may require use of a photoionization detector and/or a combustible gas indicator for entry.

Assemble the following tools, materials, and equipment as required by the estimated volume of material to be removed.

- Erosion control materials such as straw wattles or silt fence
- Aluminum or fiberglass extension ladder with an extended length of at least 10 feet
- Shovels
- Log Book
- Standard garden cultivator rake or equivalent
- Pry bars and other manual tools for breaking up crust
- Air compressor, chippers or air hammers, and/or other tools for breaking up crust
- Backhoe with a hoe ram attachment (as needed)
- Vacuum truck or equivalent to remove loose media (optional)
- Dump truck or other means of containment and transport for spent material
- Polyethylene tarp (such as Visqueen) or equivalent
- Pea gravel
- Zero-valent iron (as required)
- Pump capable of draining treatment cell along with necessary hoses and storage tanks (if needed)
- Portable generator (if needed)

Perform the following steps:

1. Establish erosion controls downgradient of the area that will be disturbed by the construction activities.

2. Prior to entry, open the access doors on each treatment cell and allow treatment cells to ventilate for a minimum of five minutes before entry. Handrails, doors and frames may be removed to allow better access. The treatment cell tops are welded to the cells and cannot be removed.

3. **If** removed media is not immediately placed into a waste container, **then** set up a staging area for the spent iron and gravel. Create a bermed area capable of holding the volume of material planned to be removed, cover it with polyethylene tarp and place plywood boards or the equivalent on top of the polyethylene tarp to hold it down and minimize damage from the removed materials.

4. Measure and record the depth to the top of the water and to the top of the media in the maintenance log. Note: The level of the media and the water level might not be the same after media replacement. The final level is based on the height of the effluent lines and maintaining the height of water over the top of gravel/iron mixture as described in Table 3.

5. Close the valve(s) on the influent line to the system.

6. Remove water by placing a pump or pump intake into treatment cell (into a depression if possible). Place pump discharge line into collection trench sump, or into a storage tank. Remove as much water as possible to expose media. Remove pump and/or intake line. The pump intake may be placed into the siphon breaks if this is more convenient.

7. After media is exposed, remove as much loose material as possible with a suction line from a vacuum truck or a backhoe.

8. Break up hardened material either using the backhoe with hoe ram attachment or hand held equipment. Repeat media removal steps as needed to remove all of the planned material out of each treatment cell. Continue water removal as necessary.

**Note – The treatment cell walls are made of HDPE. Use caution when working near the walls. All damage must be repaired prior to media replacement.**

9. **If** using a backhoe, **then** break up the material in the center of the treatment cell keeping 6-12 inches away from the vessel wall. Remove as much media as possible in this manner.

10. **If** using hand held equipment, **then** place the ladder in the treatment cell and tie it off securely. Use air hammers with chisel attachments (or equivalent) to remove remaining material next to wall of treatment cell and loosen other material as needed.

11. Removed iron and gravel shall be placed in the waste containers or staging area. This material shall be packaged or containerized as directed by RISS Radiological Engineering and Environmental Compliance.

**Note – If replacement iron appears oxidized (rusted or clumping), do not use.**

12. After the material is removed, then add zero-valent iron until it reaches the height specified in Table 3.

13. Verify that the height of the iron is at the specified depth below the doors on the vessel (Table 3).

**Note – The height of the zero-valent iron shall be a minimum of 1.5 feet below the bottom of the influent opening to the vessel, regardless of the volume of iron added to the treatment cell or as listed on Table 3.**

14. Once the iron has been added (if any), the surface shall be raked level.

15. Add a mixture of 10% iron and 90% pea gravel by volume as per table 3 but not higher than 1.5 feet below the bottom of the cell influent opening. The gravel/iron shall be completely mixed in concrete mixer or similar mixing device. The resulting volume will likely be closer to the volume of pea gravel because the iron will fill the void space in the pea gravel. Do not overfill the treatment cell.

16. Rake the top of the gravel/iron mixture to level it.

17. Once all work on the treatment cell is complete, remove the ladder and replace the railings and doors if previously removed.

9

18. Open the valves to ensure that the treatment cells will operate in series and then open up the valve on the influent line.
19. Place a board or other flat surface on the gravel/iron mixture inside the treatment cell to minimize disturbance of the media and add clean water to immediately submerge the media. Allow the vessel to fill and then check the water level and make sure its height is correct in accordance to Table 3. If a storage tank was used to contain water pumped from the cells, this water should be returned to the top of the first cell or the trench sump.
20. If the gravel/iron mixture is not submerged below the water at the depth in Table 3, immediately remove the excess material.

**Note – The gravel/iron mixture shall not extend above the water surface at any time.**

21. Remove the board from the treatment cell.
22. Rinse tools with clean water and discharge the rinse water to the treatment cell. Close the treatment cell doors.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

23. Polyethylene tarps, personal protective equipment, and other materials shall be dispositioned as directed by management. This is expected to be sanitary waste.

## 3.8 Total Iron Media Replacement at the MSPTS and ETPTS

**Note – if entry into any of the system components is required, non-permit required confined space entry requirements apply.**

The following steps are for complete replacement of the media. Appendix F has photographs of previous media replacement activities.

Table 3 shows the approximate volumes of iron and gravel/iron mixture in the treatment cells. Note that this procedure can be used for partial bed replacement including replacement of just the gravel/iron layer or just the upper portion of the gravel /iron layer as needed. Details of these calculations are found in Appendix D. Specifications for the zero-valent iron are in Appendix E.

Follow requirements for non-permit required confined space entry and obtain a ladder permit as required by Standing Order 83. The Site's Confined Space Entry procedure (MAN-072-OS&IH Manual, Chapter 21) shall be followed for any entry into the treatment cells, sump or metering manhole. It is likely that hydrogen is present in the system and also possibly hydrogen sulfide, carbon monoxide, ethane and/or methane. In addition, there likely are low concentrations of volatile organic compounds in the water. These hazards shall be addressed prior to entry. Safety personnel may require use of a photoionization detector and/or a combustible gas indicator for entry.

Assemble the following tools, materials, and equipment:

- Erosion control materials such as straw wattles or silt fence
- Aluminum or fiberglass extension ladder with an extended length of at least 10 feet
- Shovels
- Log Book
- Standard garden cultivator rake or equivalent
- Pry bars and other manual tools for breaking up crust
- Air compressor, chippers or air hammers, and/or other tools for breaking up crust
- Backhoe with a hoe ram attachment (as needed)
- Vacuum truck or equivalent to remove loose media (optional)

- Polyethylene tarp (such as Visqueen) or equivalent
- Pea gravel
- Zero-valent iron
- Pump capable of draining treatment cell along with necessary hoses
- Dump truck or other means of containment and transport for spent material
- Filter fabric
- Plumber's snake (at least 50 feet long)
- Portable generator (if needed)
- All equipment required for a non-permit required confined space entry

Perform the following steps

1. Establish erosion controls downgradient of the area that will be disturbed by the construction activities.
2. Prior to entry, open the access doors on each treatment cell and allow treatment cells to ventilate for a minimum of five minutes before entry. Guardrails, doors and frames may be removed to allow better access to the treatment cell. The treatment cell tops are welded to the cells and cannot be removed.
3. **If** removed media is not immediately placed into a waste container, **then** set up a staging area for the spent iron and gravel. Create a bermed area capable of holding the volume of material planned to be removed, cover it with polyethylene tarp and place plywood boards or the equivalent on top of the polyethylene tarp to hold it down and minimize damage from the removed materials.
4. Measure and record the depth to the top of the water and to the top of the media in the maintenance log. Note: The level of the media and the water level might not be the same after media replacement. The final level is based on the heights given in Table 3.
5. Close the valve(s) on the influent line to the system.
6. Remove water by placing a pump or pump intake into treatment cell (into a depression if possible). Place pump discharge line into collection trench sump, or into a storage tank. Remove as much water as possible to expose media. Remove pump and/or intake line. The pump intake may be placed into the siphon breaks if this is more convenient.
7. After media is exposed, remove as much loose material as possible with a suction line from a vacuum truck or a backhoe.
8. Break up hardened material either using the backhoe with hoe ram attachment or hand held equipment. Repeat media removal steps as needed to remove all of the planned material out of each treatment cell. Continue water removal as necessary.

**Note – The treatment cell walls are made of HDPE. Use caution when working near the walls. All damage must be repaired prior to media replacement.**

9. **If** using a backhoe, **then** break up the material in the center of the treatment cell keeping 6-12 inches away from the vessel wall. Remove as much media as possible in this manner.
10. **If** using hand held equipment, **then** place the ladder into the treatment cell and secure. Use air hammers with chisel attachments (or equivalent) to remove remaining material next to wall of treatment cell and loosen other material as needed.
11. Remove remaining iron along with gravel at the bottom of the treatment cell. Place removed materials in a waste container or in the staging area.

**Note – There is PVC pipe at the bottom of each treatment cell. Do not use excess force when loosening iron at the bottom of the cell to avoid breaking these pipes. All broken pipes must be repaired prior to media replacement.**

12. Measure the height of the treatment cell. Also, measure the height from the bottom of the cell to the inlet piping.

//

13. After the media is removed, add gravel as listed in Table 3. Rake the gravel drainage layer so that it is level and covers any effluent piping. New filter fabric shall be cut and placed on top of the gravel layer in both treatment cells.

14. Check the lines entering and leaving the treatment cells. If there is evidence of plugging, the lines to both treatment cells shall be cleaned, preferably with a plumber's snake. While the treatment cell is empty, the snake can be pushed through the line from the second treatment cell to the first. For the second treatment cell, the snake may also be pushed through the siphon break or the line to the flow meter flume.

**Note – If replacement iron appears oxidized (rusted or clumping), do not use.**

15. Add iron to the heights listed in Table 3. Carefully add the first two feet of iron to avoid disrupting the gravel layer. Rake the iron surface level.

16. Add a mixture of 10% iron and 90% percent pea gravel by volume up to height indicated in Table 3. The gravel/iron shall be completely mixed in concrete mixer or similar mixing device. The resulting volume will likely be closer to the volume of pea gravel because the iron will fill the void space in the pea gravel. Do not overfill treatment cell. Rake the top of the gravel/iron mixture to level it.

17. Once all work on the treatment cell is complete, remove the ladder and replace the railings and doors if previously removed.

18. Open the valves to ensure that the treatment cells will operate in series and then open up the valve on the influent line.

19. Place a board or other flat surface on the gravel/iron mixture inside the treatment cell to minimize disturbance of the media and add clean water to immediately submerge the media. Allow the vessel to fill and then check the water level and make sure its height is correct in accordance to Table 3. If a storage tank was used to contain water pumped from the cells, this water should be returned to the top of the first cell or the trench sump.

20. If the gravel/iron mixture is not submerged below the water at the depth in Table 3, immediately remove the excess material.

**Note – The gravel/iron mixture shall not extend above the water surface at any time.**

21. Remove the board and the ladder from the treatment cell.

22. Rinse tools with clean water and discharge the rinse water to the treatment cell. Close the treatment cell doors.

**Note – It is very important to keep air from entering the system. After completion of maintenance, make sure doors are completely closed and that the system is isolated from outside air.**

23. Polyethylene tarps, personal protective equipment, and other materials shall be dispositioned as directed by management. This is expected to be sanitary waste.

## 3.9 Solar Ponds Plume Treatment System

The SPPTS treatment cells are not accessible; however, other components need to be routinely checked to ensure that the system is operating as planned. This includes checking pump operation, and visually inspecting the solar panel and the operating system to verify that these are in working condition,

If the Solar Ponds Plume treatment cell pump is moved or disturbed, **then** the pump needs to be set so that it maintains water levels within the range given in Table 3.

### 3.9.1 Monitoring Water Levels in the Collection Sump

Routine water level measurements are taken in nearby Piezometer 71099 as part of the Monitoring Program. Table 4 shows the normal water elevations and depth to water. On a monthly basis, compare monthly monitoring results to these Table 4 values.

**Table 4 - Normal Groundwater Depths and Elevations in SPPTS Collection Sump and Piezometer 71099**

| Location | Depth to Water (feet) | Water Elevation |
|---|---|---|
| Piezometer 71099 | Deeper than 21 | Below 5880' |
| Collection Sump * | 22'-26' | 5875'-5879' |

*Measured from top of housing (elevation=5901.44 feet)

**Note – After heavy precipitation events, the water levels in the trench may be higher than normal operating conditions, but should return to the normal range within a few days.**

**If** the pump is operating (Section 3.9.2) and water levels are rising, **then** the sump is probably plugged. Notify management and refer to Section 3.9.3.

**If** water levels within the collection trench remain elevated for more than two consecutive months after a precipitation event, **then** notify management.

### 3.9.2 Checking the SPPTS Solar Panel, Charging System, and Batteries

Check the following on the electrical system a monthly basis:

1. Check for loose or damaged wires, including checking the insulation on the wires.
2. Make sure all equipment is securely mounted.
3. The green light on the pump controller (ME 24/48) should be on. The red light for the treatment cell should not be on.

The following should be checked monthly on the solar panels:

1. The panels should be facing south and tilted at a pitch angle of about 40 degrees.
2. Remove equipment or vegetation blocking the panel.
3. The surface of the solar panels should be clean. Light dust on the surface is all right. (Note: The panels are in a fixed position and should not be moved during routine activities).

**If** the panels are more than dusty, **then** rinse with clean tap water. **If** dirt is difficult to remove, **then** wash with a wet paper towel or a wet soft cloth.

The batteries (as of December 2004) are Concorde Sun Xtender® Batteries Model PVX-2120L. These deep-cycling batteries are made specifically for back-up power for photovoltaic systems. Each 12-volt battery is sealed and "maintenance-free". Additional information on the batteries is presented in Appendix B. The lid to the battery box should remain closed at all times except during inspection and repair. The batteries need to be inspected monthly for signs of corrosion and overcharging. These signs include the following:

- Is there corrosion at the terminals?
- Do the wires appear to be damaged or oxidized?
- Are the batteries bubbling?
- Is there moisture accumulation on the top of the batteries?
- Are the batteries bulging?
- Is the battery operating at full capacity?

**If** there is evidence of damage or overcharging the batteries, **then** contact an electrician to determine if repairs are necessary.

Check the following on the charge controller. Refer to charge controller manual in Appendix B for further information and the location of status lights:

1. If there is sunlight, make sure that the charging LED (light emitting diode) is green. If it is nighttime, this light should be red.
2. Check the battery status LEDs. The red led to the right should not be steadily on. If it is near the end of daylight hours, this light should not be blinking. These are both indications that the battery is not being charged and an electrician should be consulted. The green and yellow lights mean that the battery is charged or is partially charged.
3. The battery type selector should be set to the type of batteries in use. At this time, these are sealed batteries (Concorde PVX-2120L). If not set at the appropriate battery type, using a small screwdriver, turn the selector to the appropriate battery type and count the number of flashes on the battery status lights. The number of flashes should match the battery type as stated in the manual. For example, there should be two flashes for sealed batteries.
4. Check the digital display. **If** any of the following are displayed, **then** contact an electrician for repairs.

   LVD – low voltage load disconnect

   HVD - high voltage disconnect

   Hot - high temperature disconnect

   OCP - overcurrent and short circuit protection

   0.0 - Short circuit protection (solar amp only)
5. There are three readings on the digital display. If the following are not as stated, check the manual in Appendix B to correct.
   a. The battery status should read approximately 25 to 29 volts.
   b. The solar amp reading and the load amp reading should read out the solar panel amps and not indicate an "off" setting.
   c. The solar amp should not read zero.
6. Make sure that the system has not been disconnected from the load or the solar array. The button in the upper right hand corner of the charge controller should not be lit up nor as previously stated should the digital display indicate off when it cycles through the load amp or solar amp readings.
7. Perform the diagnostic test as described in Section 5.4 of the Prostar 30 product manual in Appendix B by holding the load disconnect switch in for more than 4 seconds. After the diagnostic test is complete, make sure that neither the solar array nor the load is disconnected (the light in the upper right hand corner of the charge controller should be off and the display should read out the solar amps and load amps). If any adjustments or repairs are necessary, contact an electrician.

Twice a year, perform the following:

1. Measure the current on the solar array with an ammeter and make sure it does not exceed 30 amps
2. Check that the controller functions and LED indicators are correct for the system conditions.
3. Check voltage on batteries with a voltmeter. These should each read about 12-14 volts.

**If** any of the conditions are not met, **then** contact an electrician to determine if repairs are necessary.

### 3.9.3 SPPTS Sump Redevelopment

Due to a buildup of fine material in the collection trench, the screen on the sump is susceptible to plugging. As described in Section 3, when water levels get too high in the treatment system and the pump is functioning properly, then the sump may be clogged and needs to be evaluated to determine if redevelopment is necessary.

A water well drilling company shall be used for sump redevelopment. There are several methods to perform this work at the discretion of the water well drilling company. In the past, a surge block has been utilized and successfully restored operation to the system. An advantage of this method is that fines are removed in this process. A step-by-step procedure is not listed here since the methodology varies by technique, by the equipment used, and by the company performing the work. With time, the need for redevelopment will decrease as the system becomes more stable and the fines are removed.

### 3.9.4 SPPTS Media Replacement

Replacement of the media in the SPPTS will eventually be required. The need for media replacement will be evidenced by the inability of the system to remove nitrates or by water backing up in the system due to clogging or biofouling. It is anticipated that removal of media might be similar to the media replacement described for other treatment systems. To date, media replacement has not been performed.

To access the treatment cells, the upper soil layer shall be removed and stockpiled along with the woodchip fill over the treatment cell. A High-Density Polyethylene (HDPE) liner overlies the treatment media. If this cannot be removed intact, then a new liner shall be required.

This activity must be further evaluated by project management prior to performance.

## 4 MAINTENANCE LOGS

A maintenance log will be kept on each system to document system checks and repairs. The logs will consist of completed routine operations checklists and maintenance logs.

Forms for the systems checks are provided in Appendix C. Maintenance log forms are provided in Appendix G.

Completed maintenance logs will be kept on file with the manager responsible for these systems. In addition to providing a maintenance record, this information also will be used to interpret the flow meter data.

# Appendix A - As-Built Drawings of Groundwater Plume Treatment Systems

# Mound Plume Treatment System Final Drawings

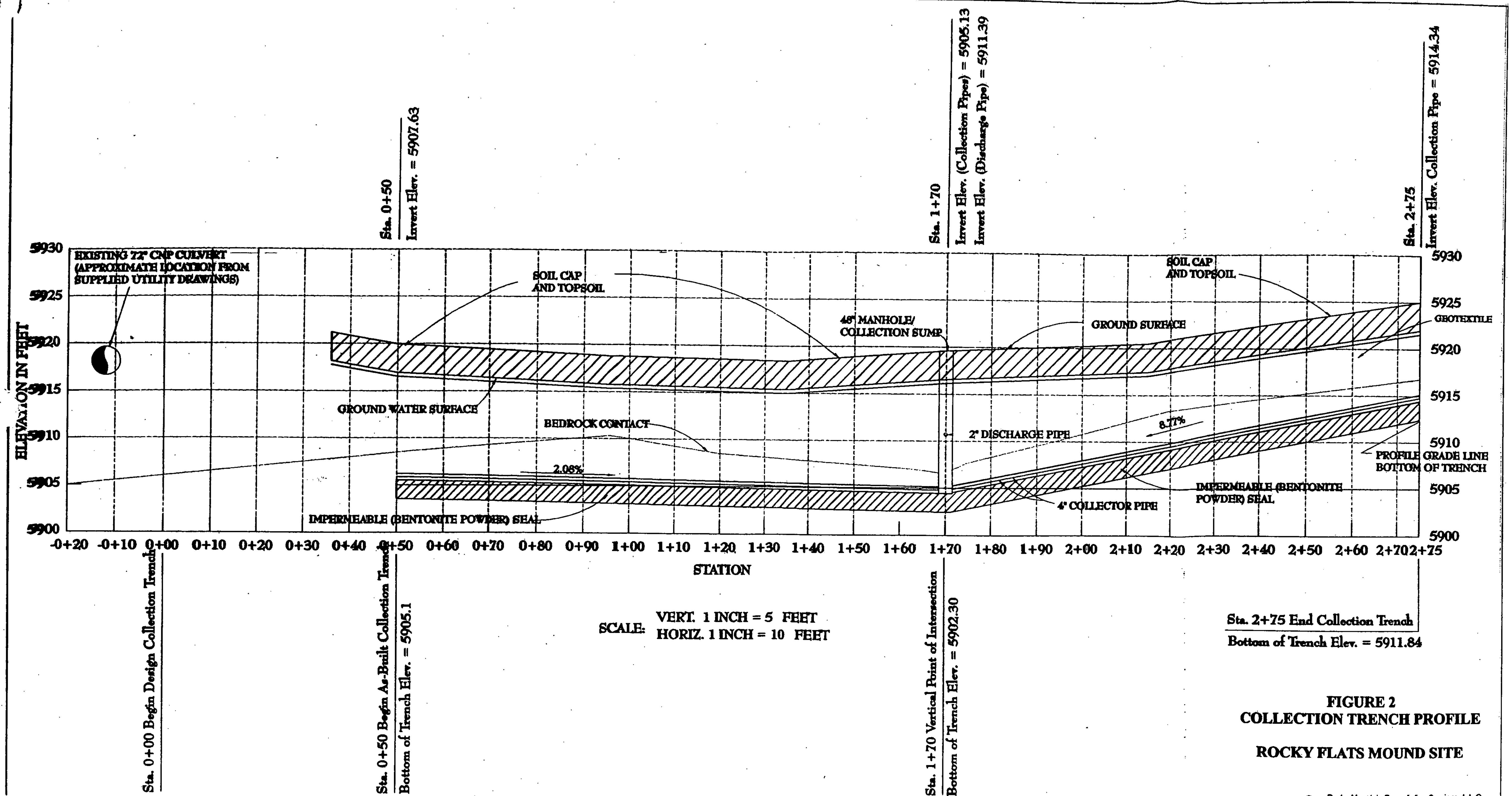



**FIGURE 2**
**COLLECTION TRENCH PROFILE**

**ROCKY FLATS MOUND SITE**

RMRS
Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

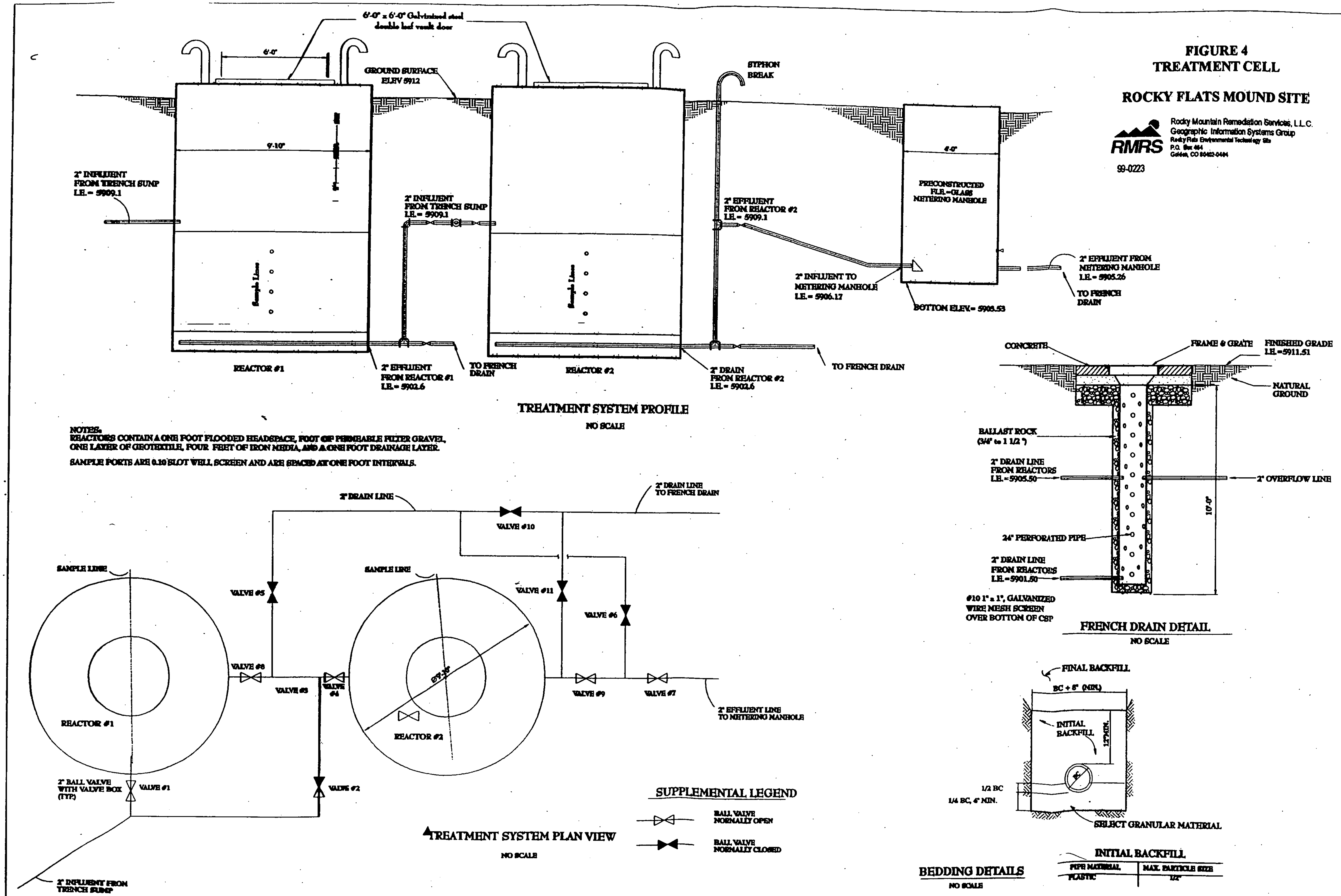
99-0223

# FIGURE 4
# TREATMENT CELL

## ROCKY FLATS MOUND SITE

Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
RMRS

99-0223




19

20

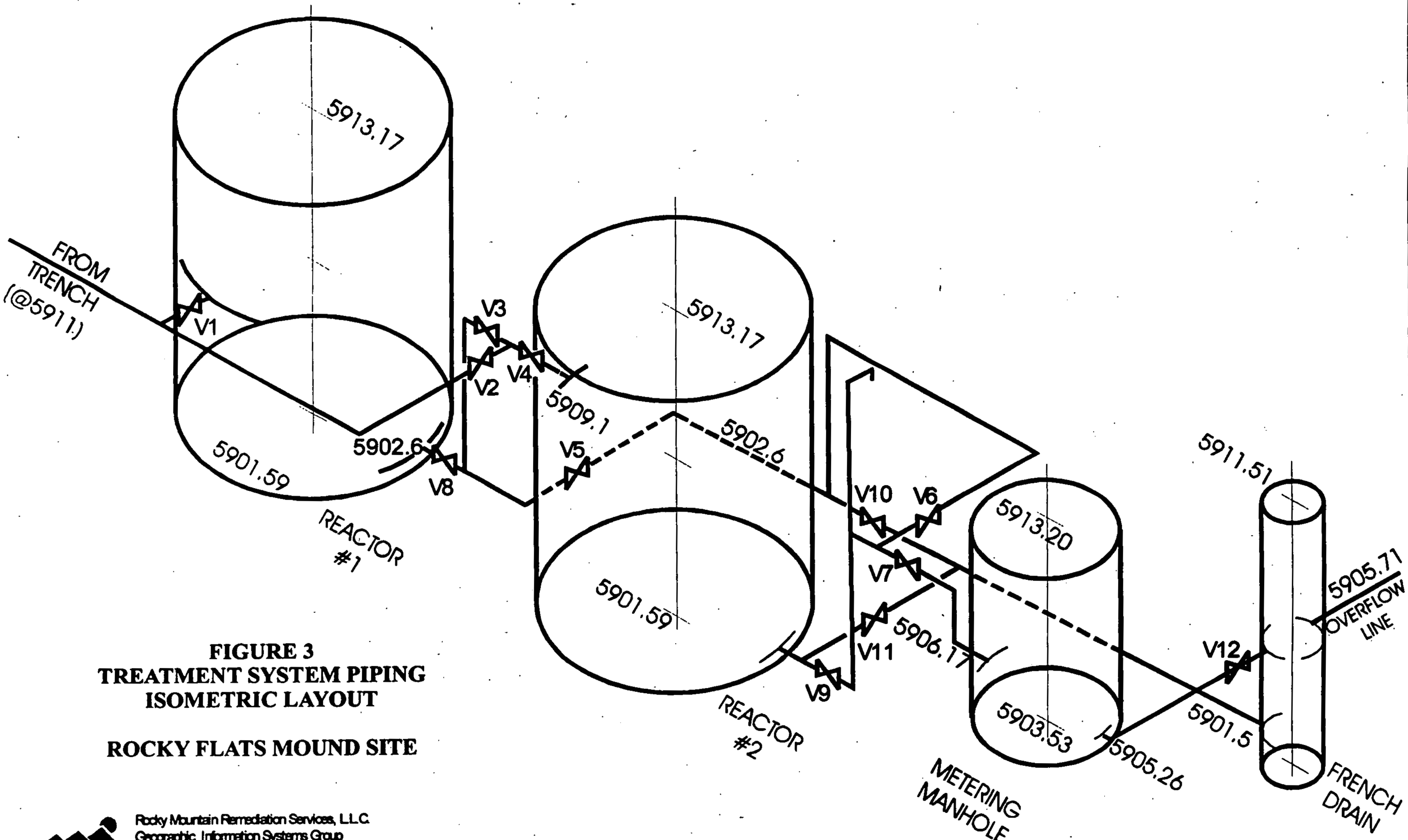



**FIGURE 3**
**TREATMENT SYSTEM PIPING**
**ISOMETRIC LAYOUT**

**ROCKY FLATS MOUND SITE**

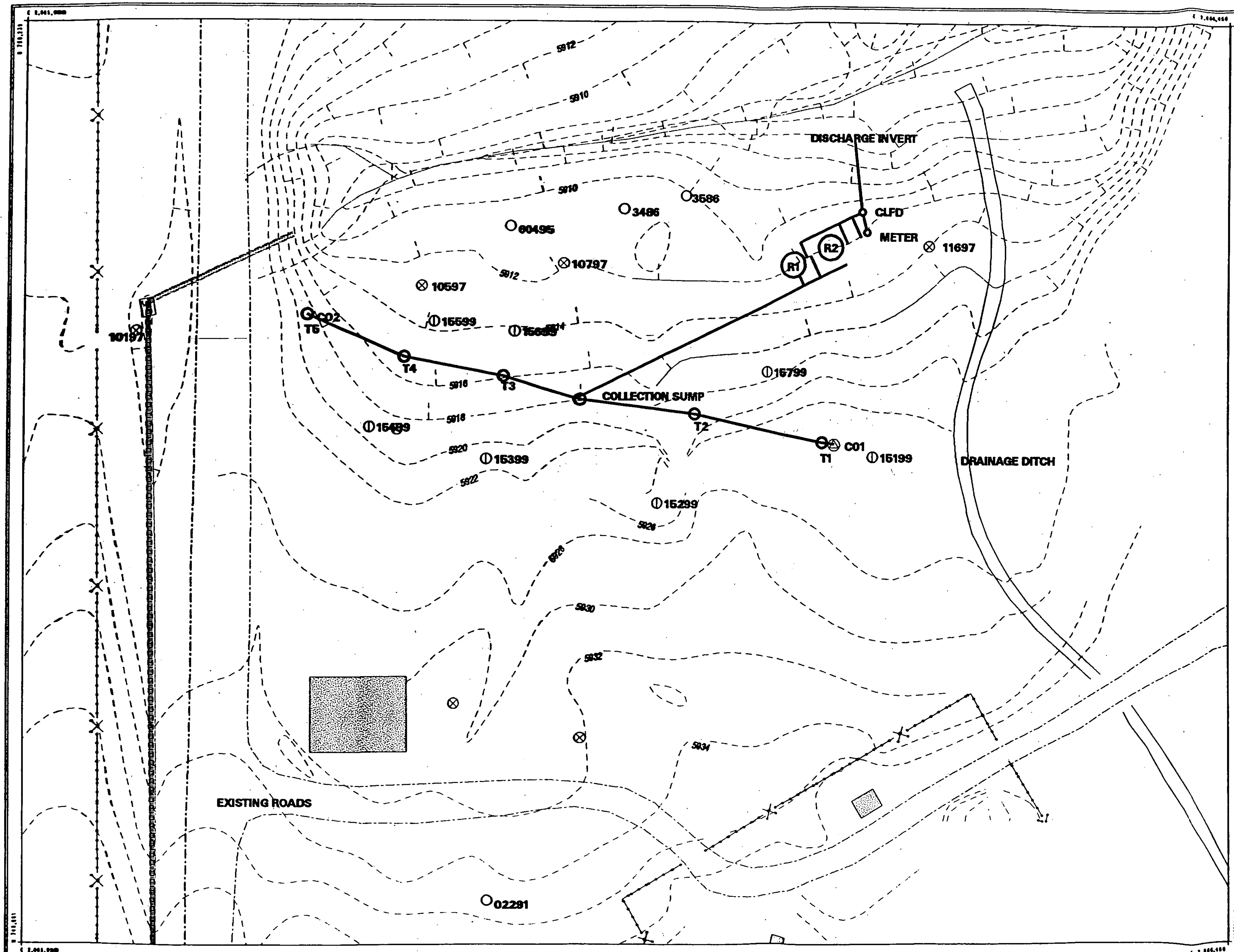
RMRS
Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

99-0223

## BARRIER WALL AND TREATMENT SYSTEM LOCATIONS

## Figure 1

Rocky Flats Environmental Technology Site




### EXPLANATION

**Detailed Key**

- New Ground Water Well
- Existing Ground Water Well
- New Trench Water-Level Monitoring Probes
- Geoprobe
- New Trench Cleanout
- Contours
- Fences
- 72" Culvert
- Trench System

**Standard Map Features**

- Buildings and other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Paved roads
- Dirt roads

DATA SOURCE:

Scale = 1 : 490
1 inch represents approximately 41 feet

10 0 20 40ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by:

RMRS Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

MAP ID: 99-0223

April 17, 1999

NT_Svr w:/projects/fy99/99-0223/aml_filename.aml

# East Trenches Plume Treatment System As-Builts

PART | QUAN. | DESCRIPTION

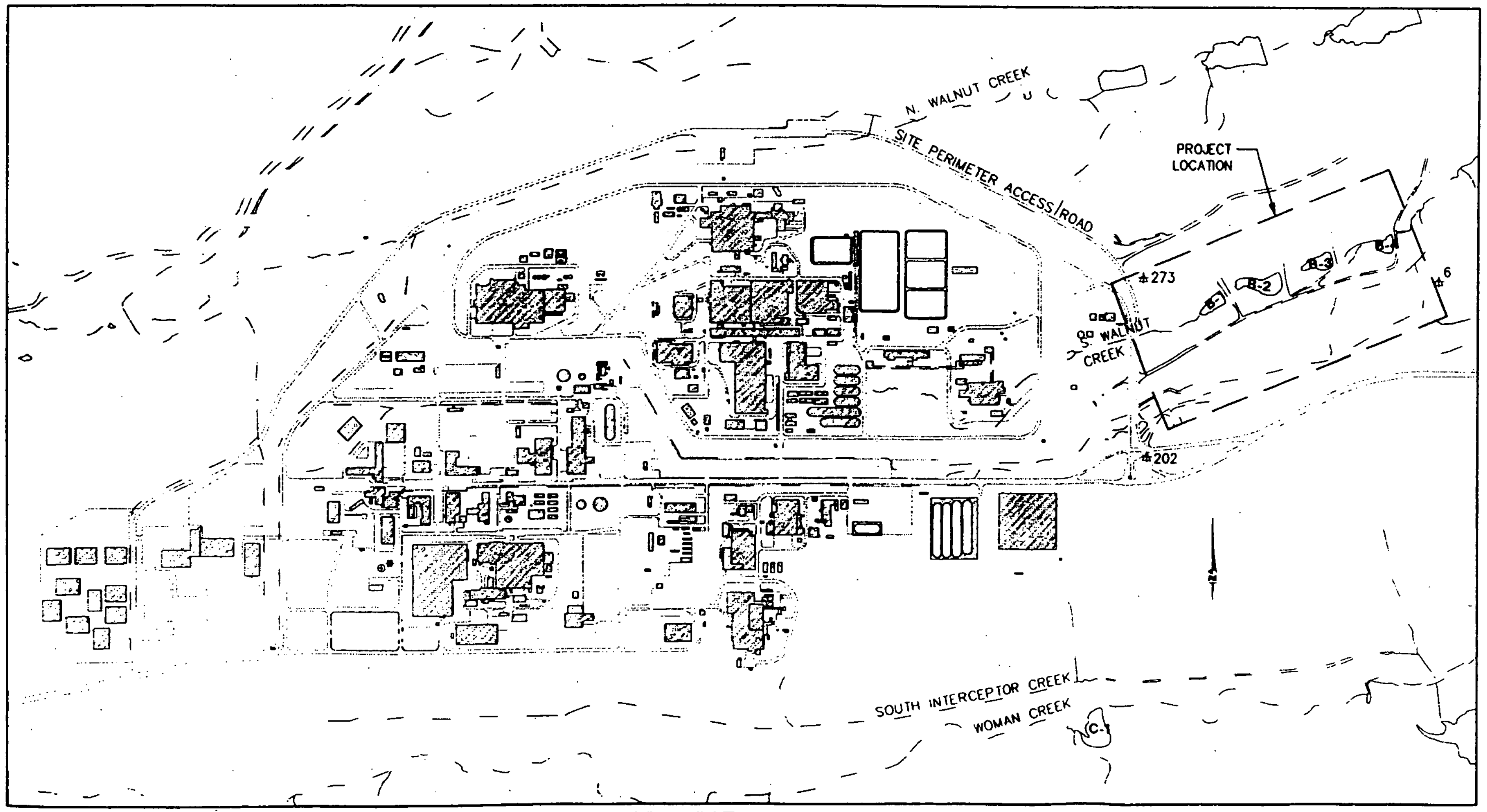
AS-BUILT DRAWINGS

# EAST TRENCHES PLUME TREATMENT SYSTEM

## ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE, GOLDEN, COLORADO

JANUARY, 2000






PROJECT LOCATION

500' 0 500'

SCALE: 1"=500'-0"

LEGEND

202 SURVEY BENCHMARK

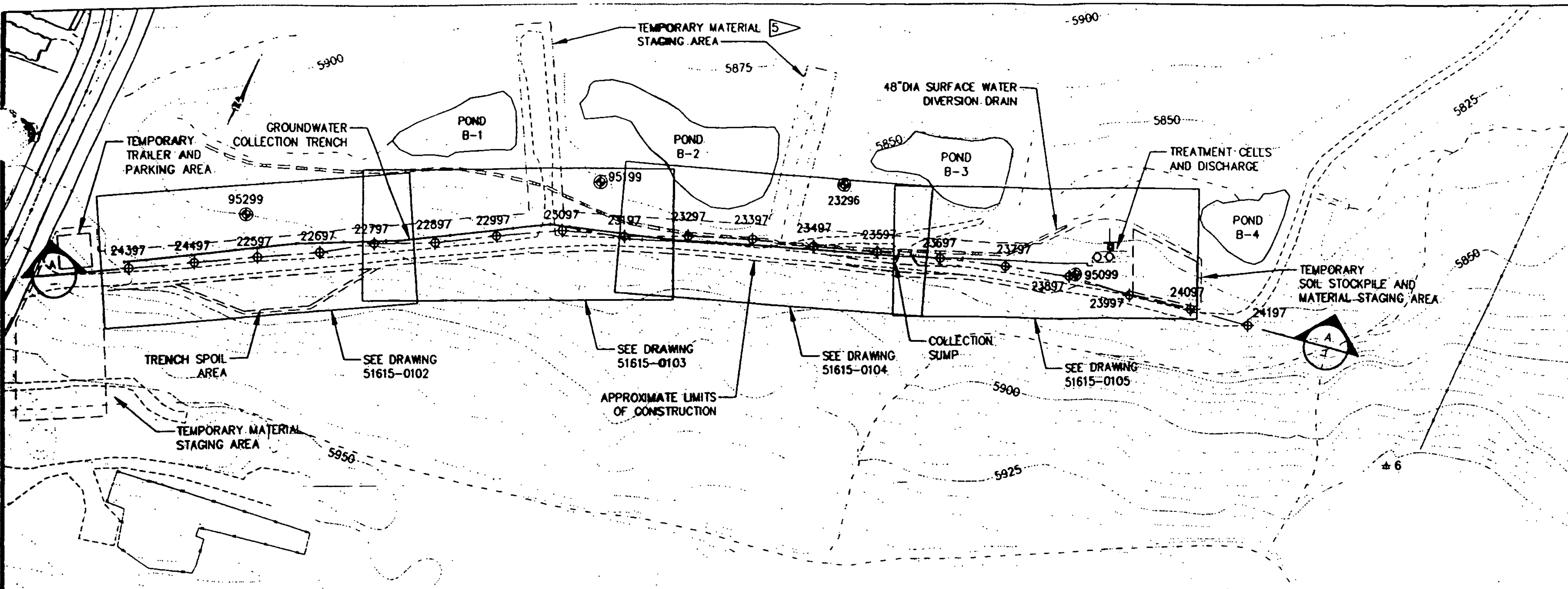
OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| A ISSUE | AS BUILT DESCRIPTION |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| TOLERANCES | FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 11/17/99 |
| DRAWN BY | HEALY JH 11/17/99 |
| CHECKED BY | STENSON |
| APPROVED BY | WILKINSON |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| NEXT ASSEMBLY | N/A |
| GRID COORD./COL. NO. | N/A |
| SCALE | AS NOTED |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | CK3500E2 |
| | U.S. DEPARTMENT OF ROCKY FLATS OFFICE GOLDEN, |
| | Rocky Flats Environmental Tec GOLDEN, COLORADC |
| | EAST TRENCHES PL TREATMENT SYSTE INDEX / TITLE SHI AND PROJECT LOCA |
| SIZE | D |
| DRAWING NUMBER | 51615-X001 |

23

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|




SITE PLAN 1 2 3 4

100' 0 100'

SCALE: 1"=100'-0"

## LEGEND

- FORMER PIEZOMETER LOCATION (REMOVED DURING CONSTRUCTION)
- MONITORING WELL
- ±6 BENCHMARK
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5950 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- A GEOLOGIC PROFILE LOCATION
- EXISTING POND

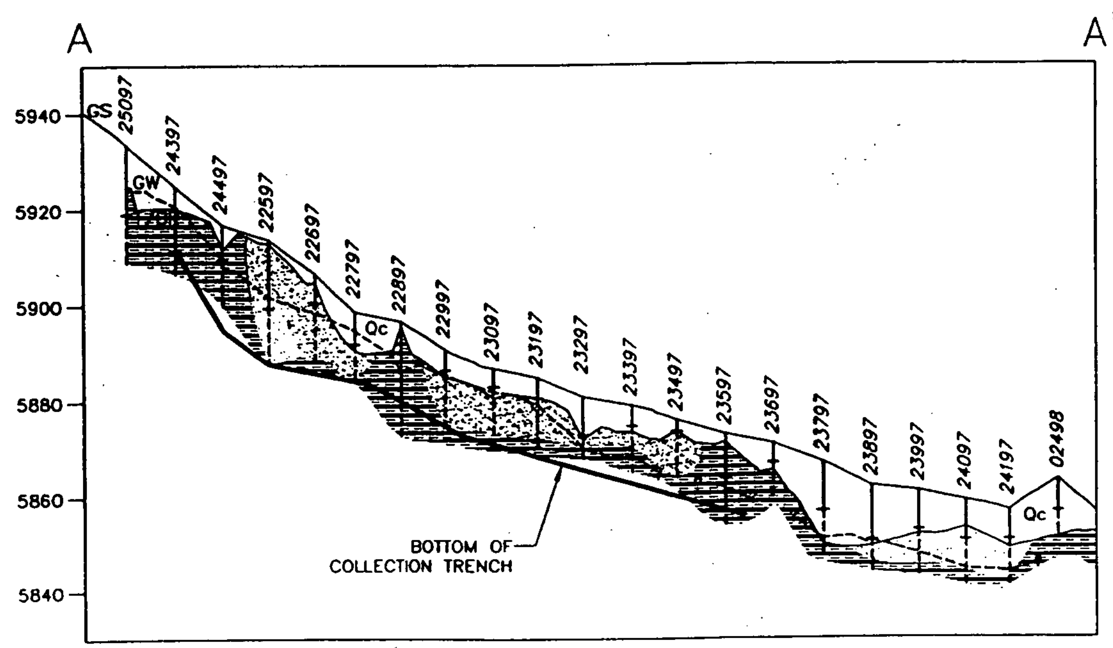
COORDINATE LIST 6

NEW MONITORING WELLS:

| | NORTHING | EASTING | GROUND ELEV | TOP OF CASING |
|---|---|---|---|---|
| 95299 | 750246.72 | 2086804.84 | 5901.80 | 5904.85 |
| 95199 | 750524.10 | 2087281.70 | 5878.86 | 5881.90 |
| 23296 | 750683.00 | 2087624.00 | 5856.00 | 5858.00 |
| 95099 | 750716.85 | 2088013.50 | 5861.07 | 5863.32 |

BENCHMARKS:

| | | | | |
|---|---|---|---|---|
| 6 | 750660.2 | 2088575.7 | 5930.8 | #4 BAR-FB983 + BM12/50 |
| 202 | 749491.2 | 2086607.1 | --- | UNKNOWN |
| 273 | 750679.4 | 2086580.7 | 5959.0 | #4BAR + CAP-TRIG ELEV |




GEOLOGIC PROFILE (FACING NORTHWEST)

## PROFILE LEGEND

- GS GROUND SURFACE
- GW GROUND WATER SURFACE
- T/BR TOP OF BEDROCK
- QrF ROCKY FLATS ALLUVIUM
- Qc COLLUVIUM
- CLAYSTONE
- SANDSTONE, UNDIFFERENTIATED ARAPAHOE/LARAMIE
- ARAPAHOE NO. 1 SANDSTONE
- 23897 MONITORING WELL OR PIEZOMETER
- SCREENED INTERVAL

HORIZONTAL GRAPHIC SCALE
0 100 200
(IN FEET)
1 inch = 200 ft.
VERTICAL SCALE
1 inch = 20 ft.

NOTES:

1. DATA SOURCE FOR BASEMAPS IS ROCKY MOUNTAIN REMEDIATION SERVICES, L.L.C. BUILDINGS, FENCES, HYDROGRAPHY, ROADS AND OTHER STRUCTURES FROM 1994 AERIAL FLY-OVER DATE CAPTURED BY EG&G RSL, LAS VEGAS. DIGITIZED FROM THE ORTHOPHOTOGRAPHS 1/95. TOPOGRAPHIC CONTOURS WERE DERIVED FROM DIGITAL ELEVATION MODEL (DEM) DATA BY MORRISON KNUDSON (MK) USING ESRI "ARC TIN" AND "LATTICE" TO PROCESS THE DEM DATA TO CREATE 5-foot CONTOURS. THE DEM DATA WAS CAPTURED BY THE REMOTE SENSING LAB, LAS VEGAS, NV, 1994 AERIAL FLYOVER AT ~ 10 METER RESOLUTION. THE DEM POST-PROCESSING PERFORMED BY MK, WINTER 1997.
2. BURIED 480 VOLT POWER OR OTHER UTILITIES MAY BE PRESENT IN THE VICINITY.
3. MAINTAIN SURFACE WATER DIVERSION DITCHES UP HILL OF LIMITS OF CONSTRUCTION.
4. MAINTAIN SILT FENCE FOR EROSION CONTROL DOWN HILL OF LIMITS OF CONSTRUCTION.
5. MAINTAIN ACCESS THROUGH STAGING AREAS AND RESTORE TO ORIGINAL CONDITION.
6. LOCATIONS SHOWN IN STATE PLANE COORDINATES.

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| ISSUE | DESCRIPTION | PROJECT/WCF NO. |
|---|---|---|
| A | AS BUILT | CK3500E2 |

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench

BLDG./FACILITY: Site — AREA: N/A — GRID COORD./COL NO.: N/A — SCALE: N/A, AS NOTED

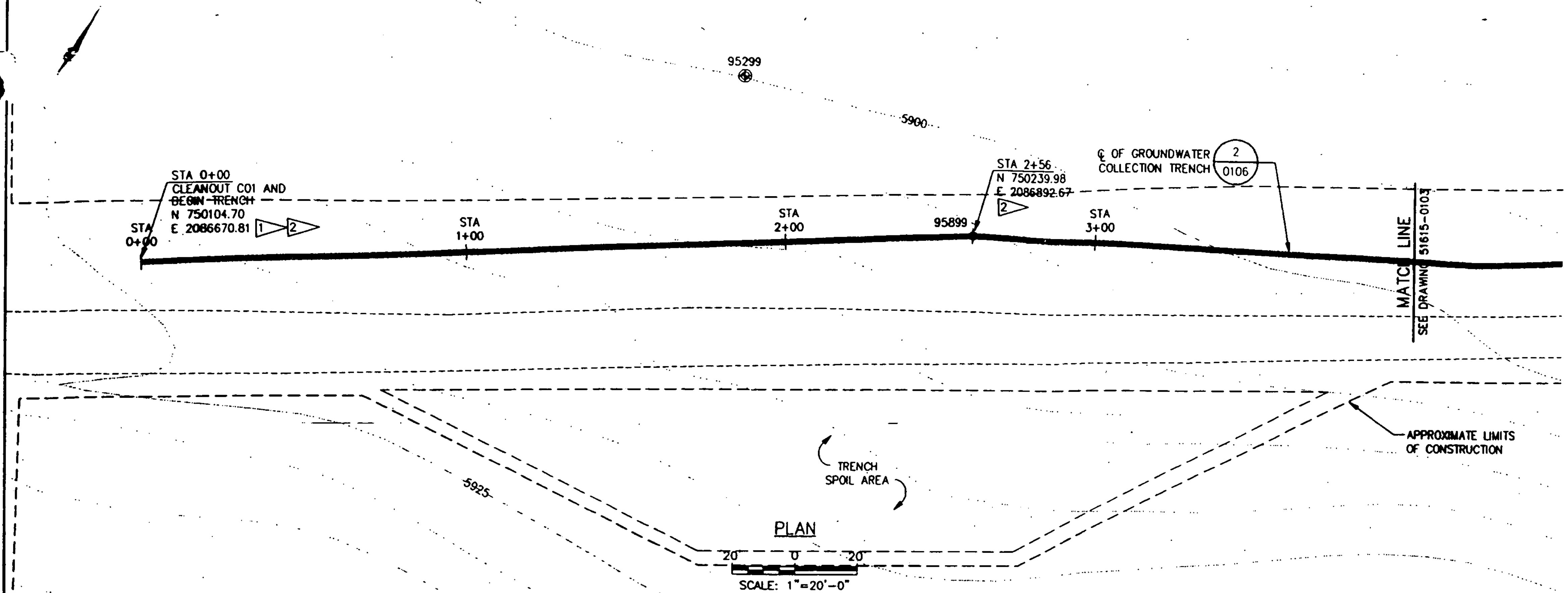
DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN KAF 12/17/99
DRAWN BY: HEALY JH 12/17/99
CHECKED BY: PARMAR
APPROVED BY: WILKINSON
CLASSIFIER: CEX-012-96
LANDLORD: PRIMROSE

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

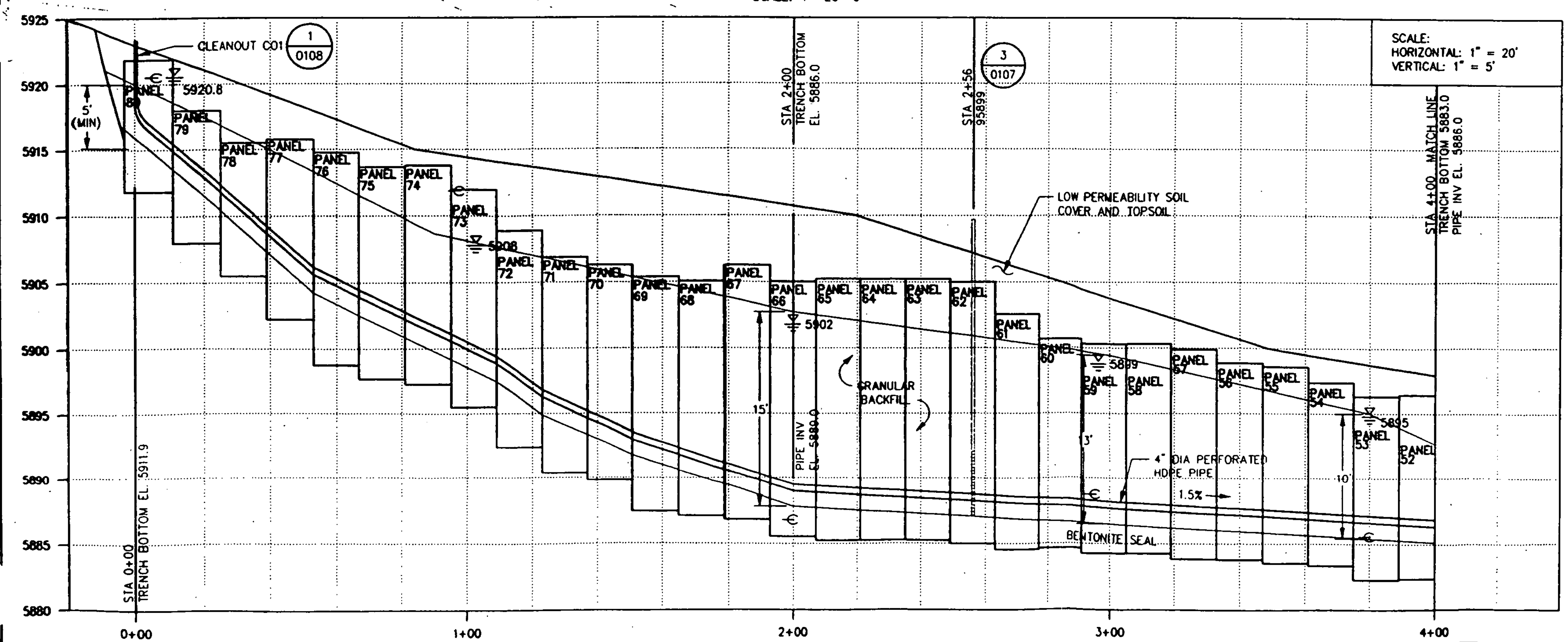
EAST TRENCHES PLUME TREATMENT SYSTEM
SITE PLAN AND GEOLOGIC PROFILE

SIZE: D — DRAWING NUMBER: 51615-0101 — ISSUE: A

AUTOCAD COMPUTER GENERATED R\ACD\51615\0101\A




## PLAN




## PROFILE

## LEGEND

- MONITORING WELL
- TRENCH PIEZOMETER
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- TOP OF CLAYSTONE BEDROCK
- HISTORICAL WATER TABLE ELEVATION (APRIL TO JUNE 1998)

NOTE:

1. LOCATIONS SHOWN IN STATE PLANE COORDINATES.
2. PIEZOMETER, CLEANOUT AND MONITORING WELL ELEVATIONS: FEET ABOVE MEAN SEA LEVEL

| Point | Northing | Easting | Ground Elevation | Top of Casing Elevation |
|---|---|---|---|---|
| PIEZOMETERS: | | | | |
| 95899 | 750239.98 | 2086892.67 | 5906.89 | 5909.38 |
| 95799 | 750433.15 | 2087238.60 | 5888.24 | 5890.62 |
| 95699 | 750550.13 | 2087561.77 | 5878.11 | 5880.51 |
| CLEANOUTS: | | | | |
| C01 | 750104.70 | 2086670.81 | 5922.87 | |
| C02 | 750312.10 | 2087036.04 | 5899.03 | |
| C03 | 750465.86 | 2087356.80 | 5884.89 | |

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| PROJECT/WCF NO. | CK3500E2 |
| KEYWORDS | 1. Contamination; 2. Groundwater; 3. Remedial; 4. Treatment; 5. Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 12/17/99 |
| DRAWN BY | HEALY JH 12/17/99 |
| CHECKED BY | PARMAR 1/4/00 |
| APPROVED BY | WILKINSON 1/4/2000 |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO

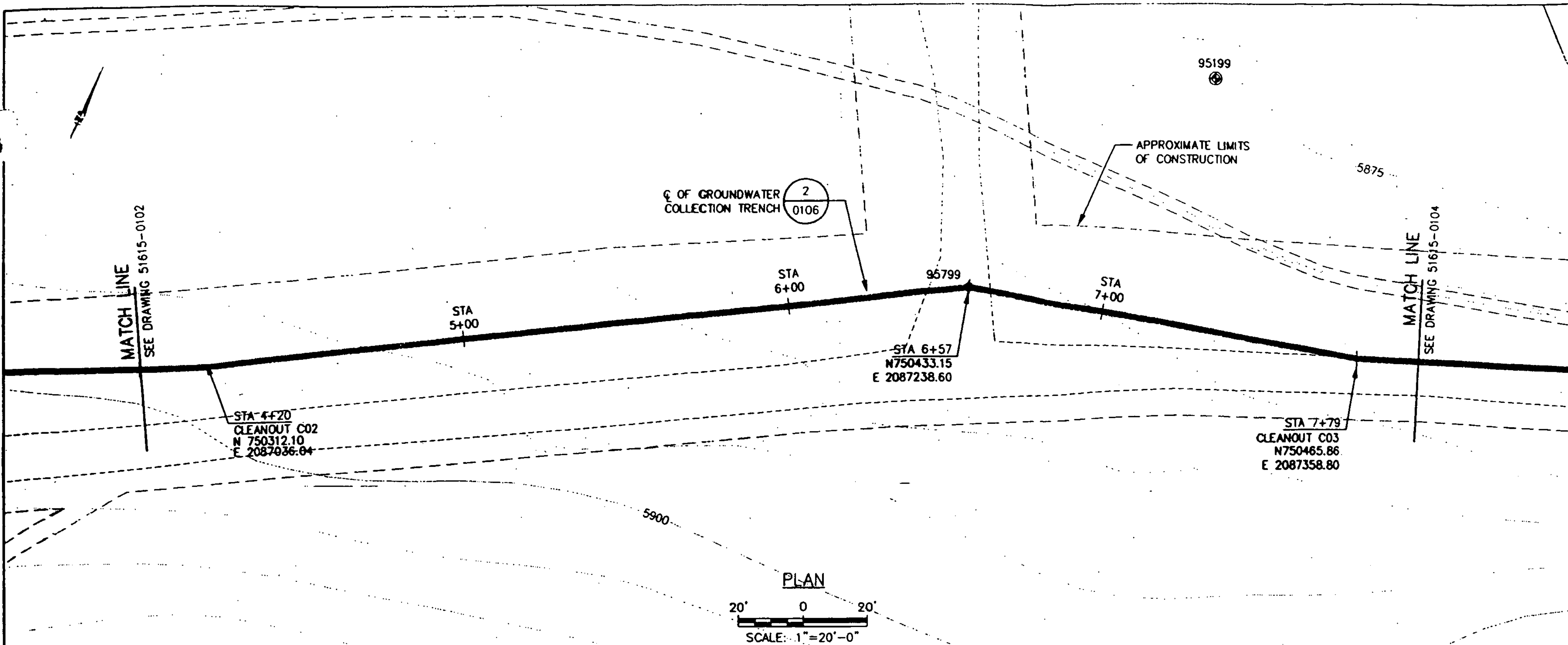
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

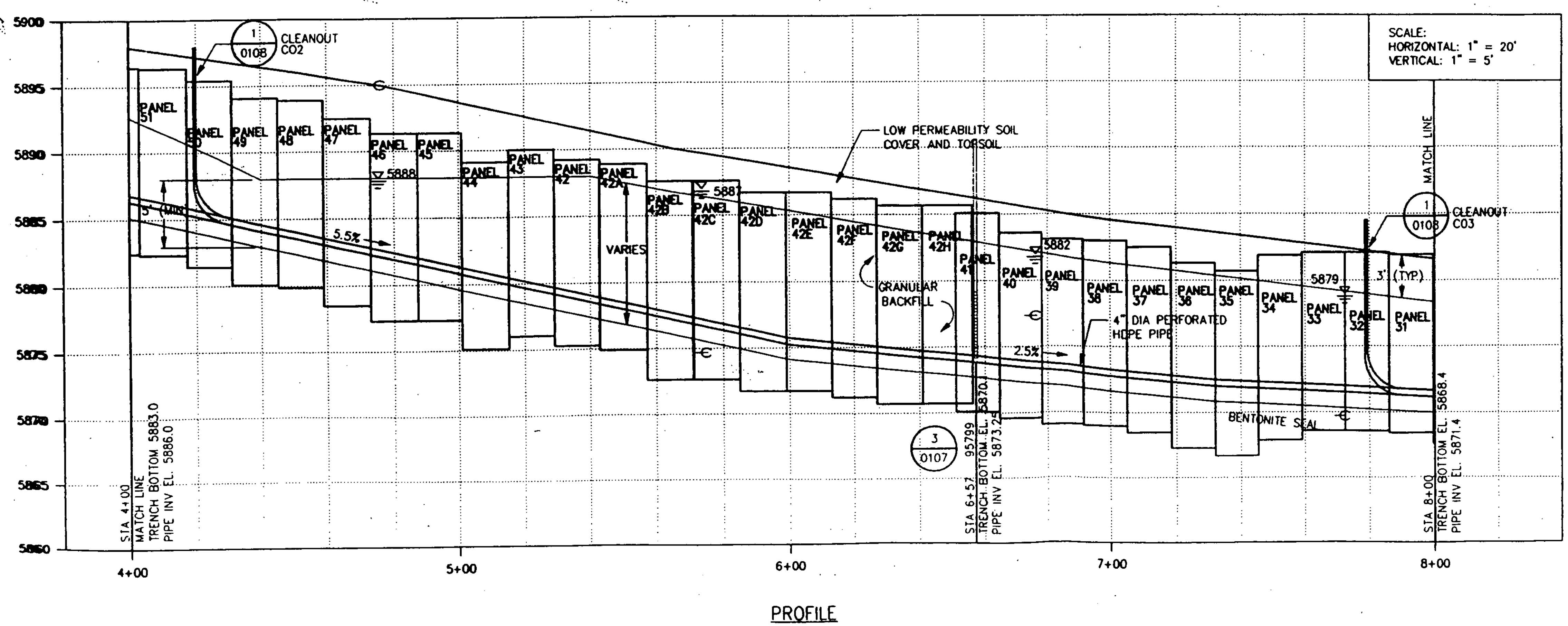
EAST TRENCHES PLUME TREATMENT SYSTEM

PLAN AND PROFILE
STA 0+00 TO STA 4+00

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0102 | A |

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|




## LEGEND

- MONITORING WELL
- TRENCH PIEZOMETER
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5900 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- EXISTING 48" DIAMETER BURIED CORRUGATED METAL PIPE DIVERSION DRAIN 1
- TOP OF CLAYSTONE BEDROCK
- HISTORICAL WATER TABLE ELEVATION (APRIL TO JUNE 1998)

NOTES:

1. LOCATION OF BURIED DIVERSION DRAIN IS APPROXIMATE. UNCOVER TOP OF DRAIN NEAR PROJECT AREA BEFORE EXCAVATING COLLECTION TRENCH TO VERIFY DRAIN LOCATION.
2. LOCATIONS SHOWN IN STATE PLANE COORDINATES.

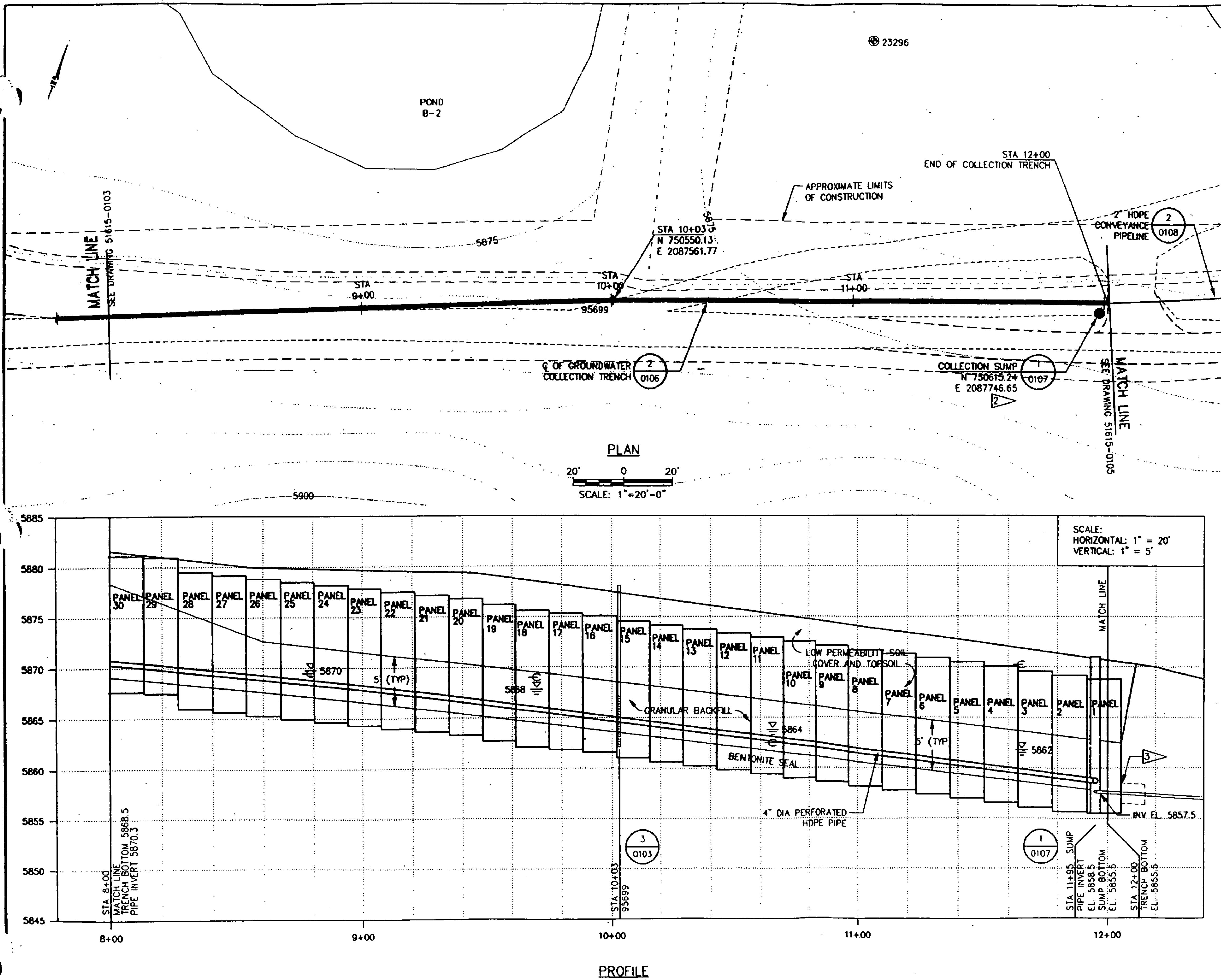
OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | | | |
|---|---|---|---|
| A ISSUE | AS BUILT DESCRIPTION | | CK3500E2 PROJECT/WCF NO. |
| KEYWORDS | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO |
| 1.Contamination | | DESIGNED BY FRIESEN KAF 12/17/99 | Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| 2.Groundwater | | DRAWN BY HEALY JH 12/17/99 | |
| 3.Remedial | | CHECKED BY PARMAR 1/1/00 | EAST TRENCHES PLUME TREATMENT SYSTEM |
| 4.Treatment | | APPROVED BY WILKINSON 1/4/2000 | PLAN AND PROFILE STA 4+00 TO STA 8+00 |
| 5.Trench | REMOVE BURRS AND SHARP EDGES | | |
| BLDG./FACILITY Site | NEXT ASSEMBLY N/A | CLASSIFIER CEX-012-96 | SIZE D |
| ROOM/AREA N/A | SCALE: AS NOTED | LANDLORD PRIMROSE | DRAWING NUMBER 51615-0103 |
| GRID COORD./COL NO. N/A | | | ISSUE A |

AUTOCAD COMPUTER GENERATED R:\ACD\51615\0103\A

26




| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

## LEGEND

- MONITORING WELL
- TRENCH PIEZOMETER
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FINAL ROAD REALIGNMENT
- FENCE
- 5900 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- 48" DIAMETER BURIED CORRUGATED METAL PIPE DIVERSION DRAIN 1
- TOP OF CLAYSTONE BEDROCK
- HISTORICAL WATER TABLE ELEVATION (APRIL TO JUNE 1998)

NOTES:

1. LOCATION OF BURIED DIVERSION DRAIN IS APPROXIMATE. UNCOVER TOP OF DRAIN NEAR PROJECT AREA BEFORE EXCAVATING COLLECTION TRENCH TO VERIFY DRAIN LOCATION.
2. LOCATIONS SHOWN IN STATE PLANE COORDINATES. (SUMP COORDINATES CORRESPOND TO CENTER POINT)
3. REPLACE 10 LF PIPE BEDDING WITH BENTONITE SEAL.

OHM Energy Services Corporation
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

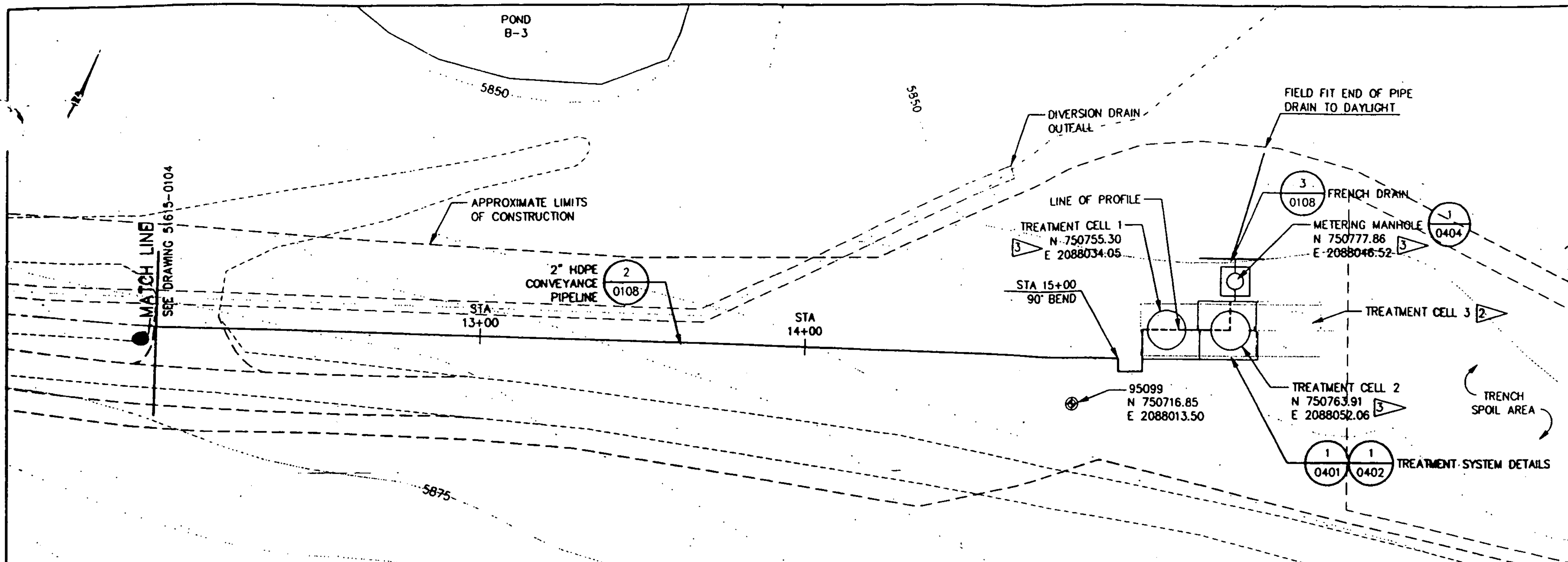
| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 12/17/99 |
| DRAWN BY | HEALY JH 12/17/99 |
| CHECKED BY | PARMAR 1/4/00 |
| APPROVED BY | WILKINSON 1/4/00 |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | CK3500E2 |

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

EAST TRENCHES PLUME TREATMENT SYSTEM
PLAN AND PROFILE
STA 8+00 TO STA 12+00

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0104 | A |

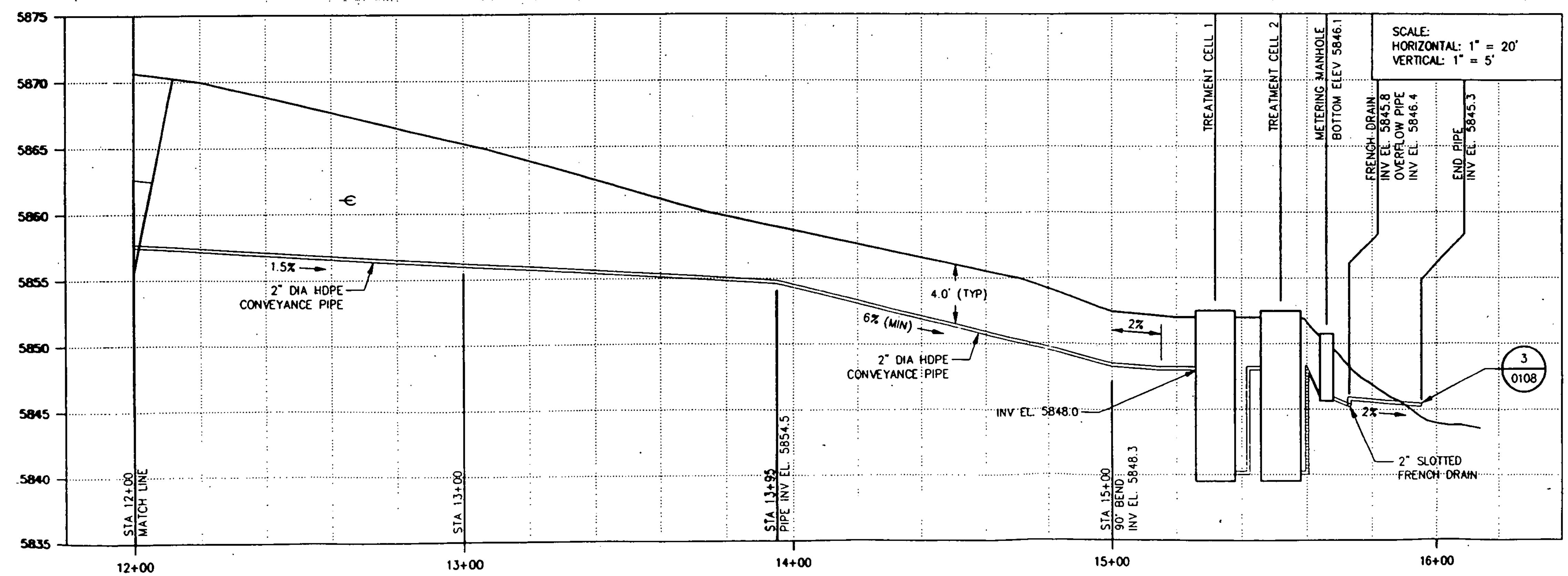
27




PLAN

20' 0 20'

SCALE: 1"=20'-0"




PROFILE

## LEGEND

- MONITORING WELL
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5900 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- 48" DIAMETER BURIED CORRUGATED METAL PIPE DIVERSION DRAIN 1
- TOP OF CLAYSTONE BEDROCK

NOTES:

1. LOCATION OF BURIED DIVERSION DRAIN IS APPROXIMATE.
2. TREATMENT CELL 3 IS FUTURE.
3. LOCATIONS SHOWN IN STATE PLANE COORDINATES. (COORDINATES FOR TREATMENT CELLS AND METERING MANHOLE CORRESPOND TO CENTER POINT)

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

| ISSUE | DESCRIPTION |
|---|---|
| A | AS BUILT |

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench

BUILDING/FACILITY: Site — AREA: N/A — GRID COORD.: N/A — SCALE: AS NOTED

| | | |
|---|---|---|
| DESIGN COMPANY: OHM/Parsons | | |
| DESIGNED BY: FRIESEN | KAF | 12/17/99 |
| DRAWN BY: HEALY | JH | 12/17/99 |
| CHECKED BY: PARMAR | | 1/4/00 |
| APPROVED BY: WILKINSON | | 1/4/2000 |
| CLASSIFIER: CEX-012-96 | | |
| LANDLORD: PRIMROSE | | |

CK3500E2 PROJECT/WCF NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

EAST TRENCHES PLUME TREATMENT SYSTEM
PLAN AND PROFILE STA 12+00 TO 15+00

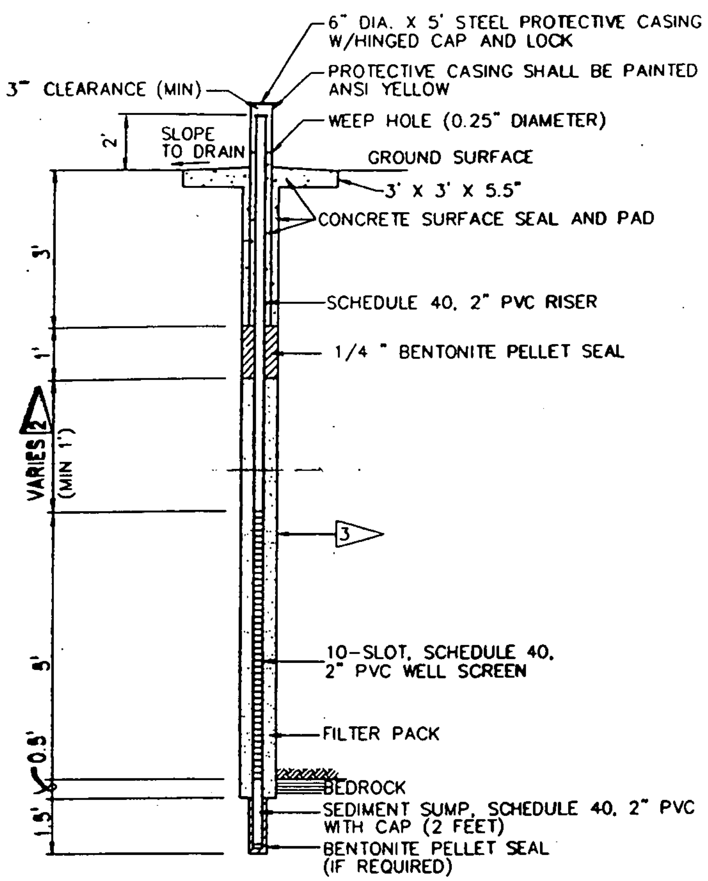
SIZE: D — DRAWING NUMBER: 51615-0105 — ISSUE: A

28

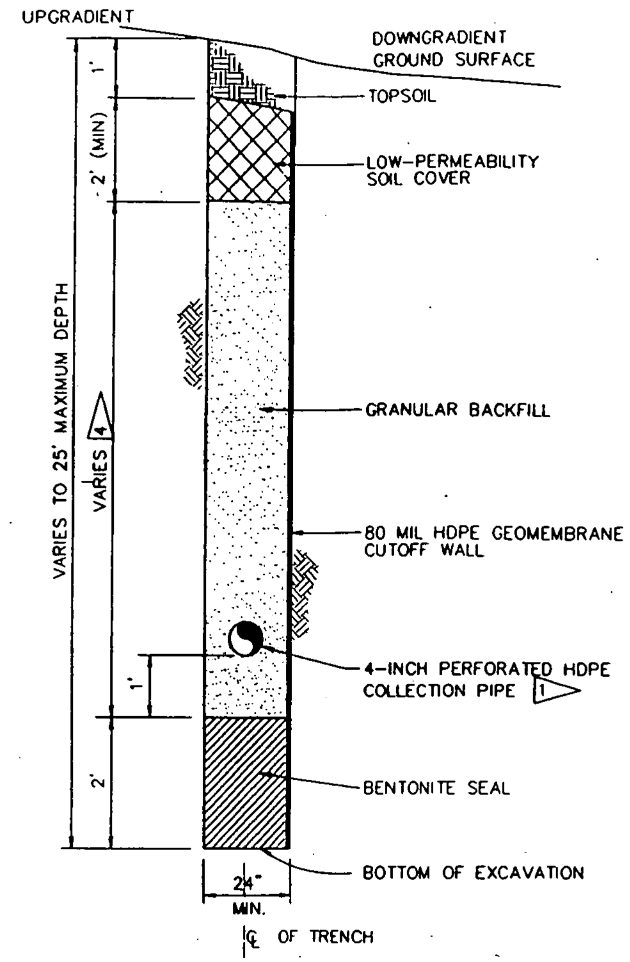
| PART | QUAN | DESCRIPTION | MATERIAL |
|---|---|---|---|

NOTES:

1. COLLECTION PIPE TO BE PLACED ON A MINIMUM OF 12 INCHES OF GRANULAR BACKFILL.
2. THE MONITORING WELLS SHALL BE INSTALLED SO THAT THE SCREENED INTERVAL BEGINS AT TOP OF BEDROCK. SUBCONTRACTOR WILL DETERMINE DEPTH BASED ON SITE SPECIFIC GEOLOGY AT TIME OF DRILLING.
3. MONITORING WELL BORING AND INSTALLATION PERFORMED WITH 6.25-INCH I.D. HOLLOW STEM AUGERS, SUMP SOCKET 3-INCH O.D. HOLE.
4. SEE DRAWINGS 51615-0102 THROUGH 51615-0104 FOR PROFILE GRADE ELEVATIONS.




1/X TYPICAL 2" MONITORING WELL DETAIL
NOT TO SCALE




2/X TYPICAL GROUNDWATER COLLECTION TRENCH CROSS SECTION
NOT TO SCALE

OHM Energy Services Corporation
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 11/17/99 |
| DRAWN BY | HEALY JH 11/17/99 |
| CHECKED BY | STENSON |
| APPROVED BY | WILKINSON |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | CK3500E2 |

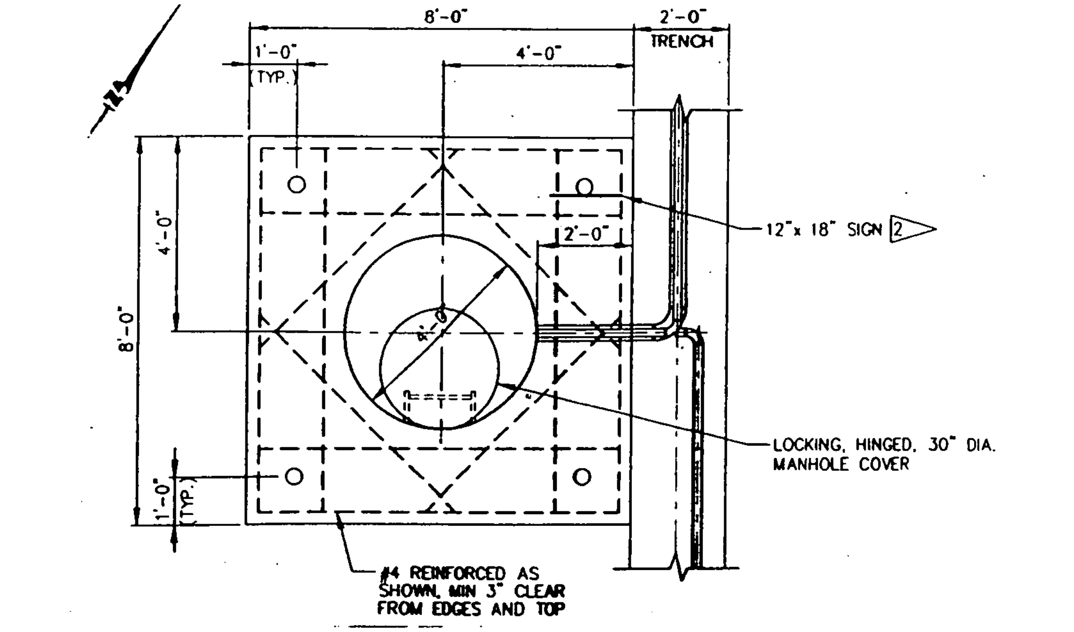
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

EAST TRENCHES PLUME TREATMENT SYSTEM
MONITORING WELL DETAIL AND COLLECTION TRENCH SECTION

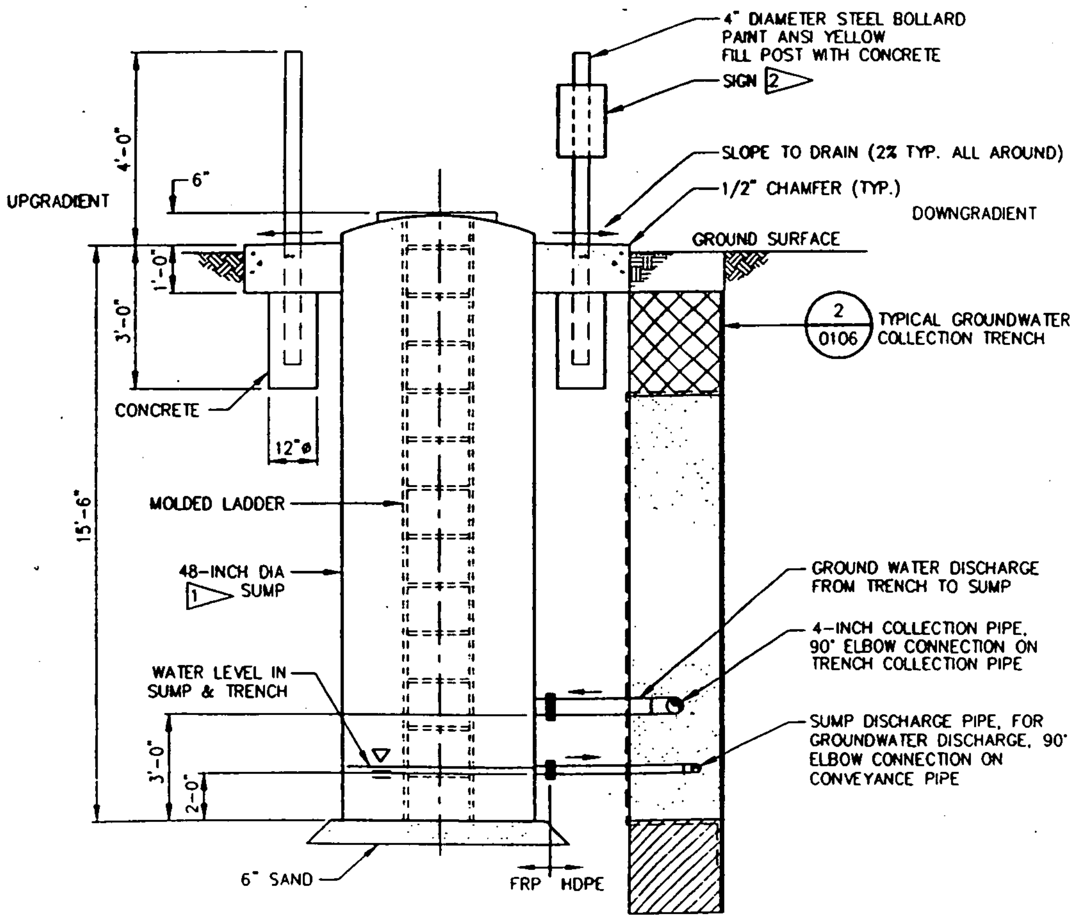
| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0106 | A |

29

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

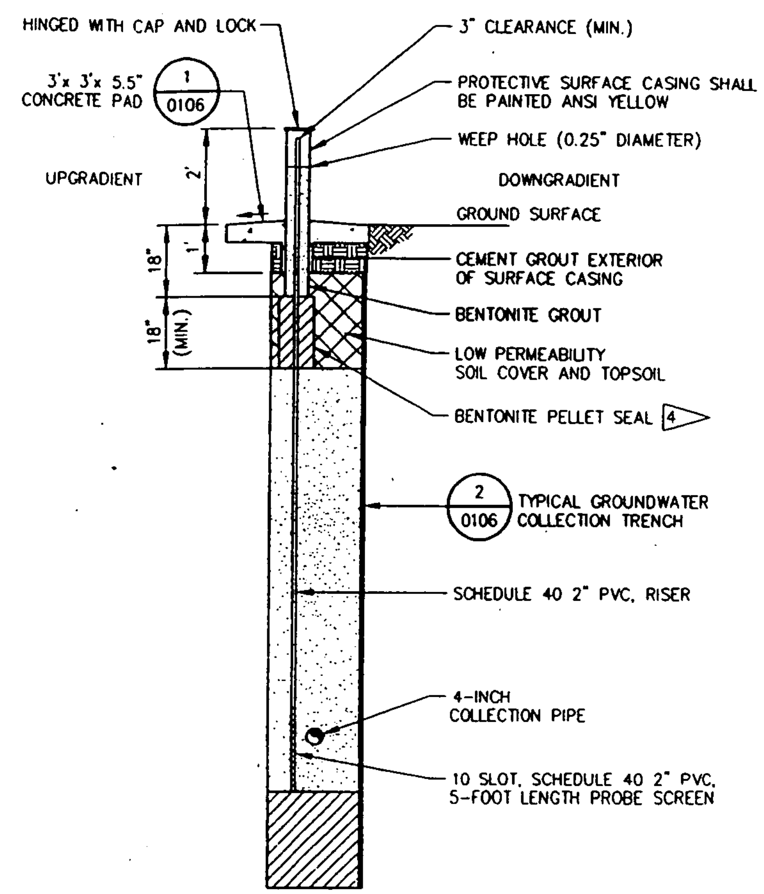



PLAN




SECTION

1 COLLECTION TRENCH SUMP DETAIL
NOT TO SCALE




3 TYPICAL TRENCH PIEZOMETER CROSS SECTION
NOT TO SCALE 3

NOTES:

1. SUMP CONSTRUCTED OF FIBERGLASS REINFORCED POLYESTER WITH PREFORMED LADDER AND HINGED, LOCKABLE COVER.
2. 1/8-INCH THICK STEEL SIGN, ATTACH TO BOLLARD. PAINT WHITE WITH BLACK LETTERING 2" MIN HEIGHT. SIGN TO READ "CONFINED SPACE PERMIT REQUIRED FOR ENTRY"
3. TRENCH PIEZOMETER LOCATIONS ARE SHOWN ON DRAWINGS 0102 THROUGH 0104.
4. PROVIDE HYDRATED BENTONITE SEAL BETWEEN PVC RISER PIPE AND SURFACE CASING, AND A MINIMUM 2" THICKNESS AROUND EXTERIOR OF SURFACE CASING AS SHOWN.

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver Colorado (303) 831-8100

A ISSUE | AS BUILT DESCRIPTION

CK3500E2 PROJECT/WCF NO.

KEYWORDS
1.Contamination
2.Groundwater
3.Remedial
4.Treatment
5.Trench

BLDG./FACILITY Site
ROOM/AREA N/A
GRID COORD./COL. NO. N/A

TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE
REMOVE BURRS AND SHARP EDGES
NEXT ASSEMBLY N/A
SCALE: AS NOTED

DESIGN COMPANY: OHM/Parsons
DESIGNED BY FRIESEN KAF 11/17/99
DRAWN BY HEALY JH 11/17/99
CHECKED BY STENSON
APPROVED BY WILKINSON
CLASSIFIER CEX-012-96
LANDLORD PRIMROSE

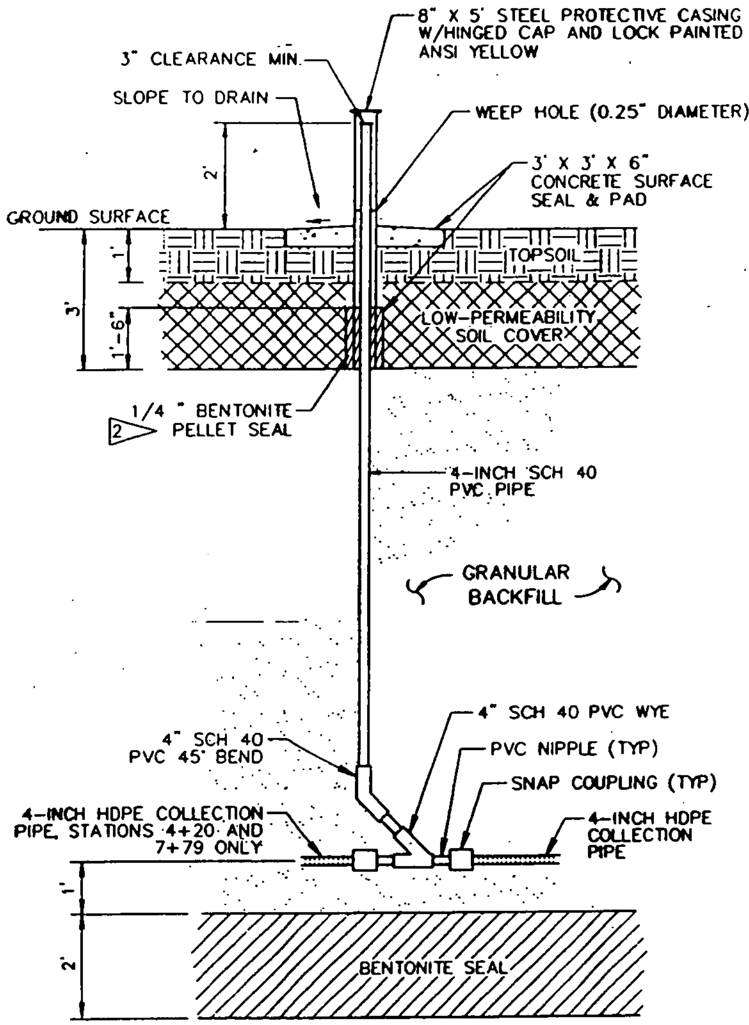
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO

Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

EAST TRENCHES PLUME TREATMENT SYSTEM

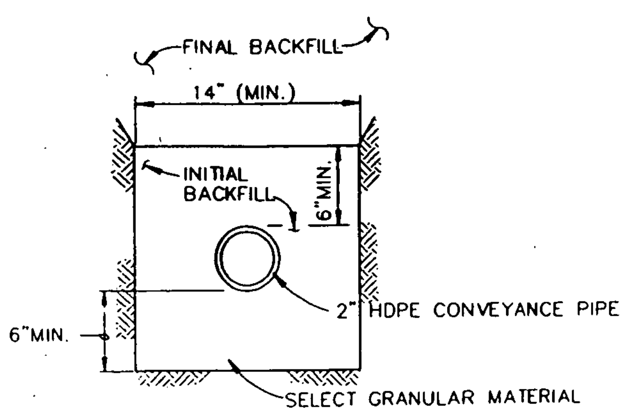
SUMP AND TRENCH PIEZOMETER SECTIONS

SIZE D | DRAWING NUMBER 51615-0107 | ISSUE A




1 COLLECTION PIPE CLEANOUTS

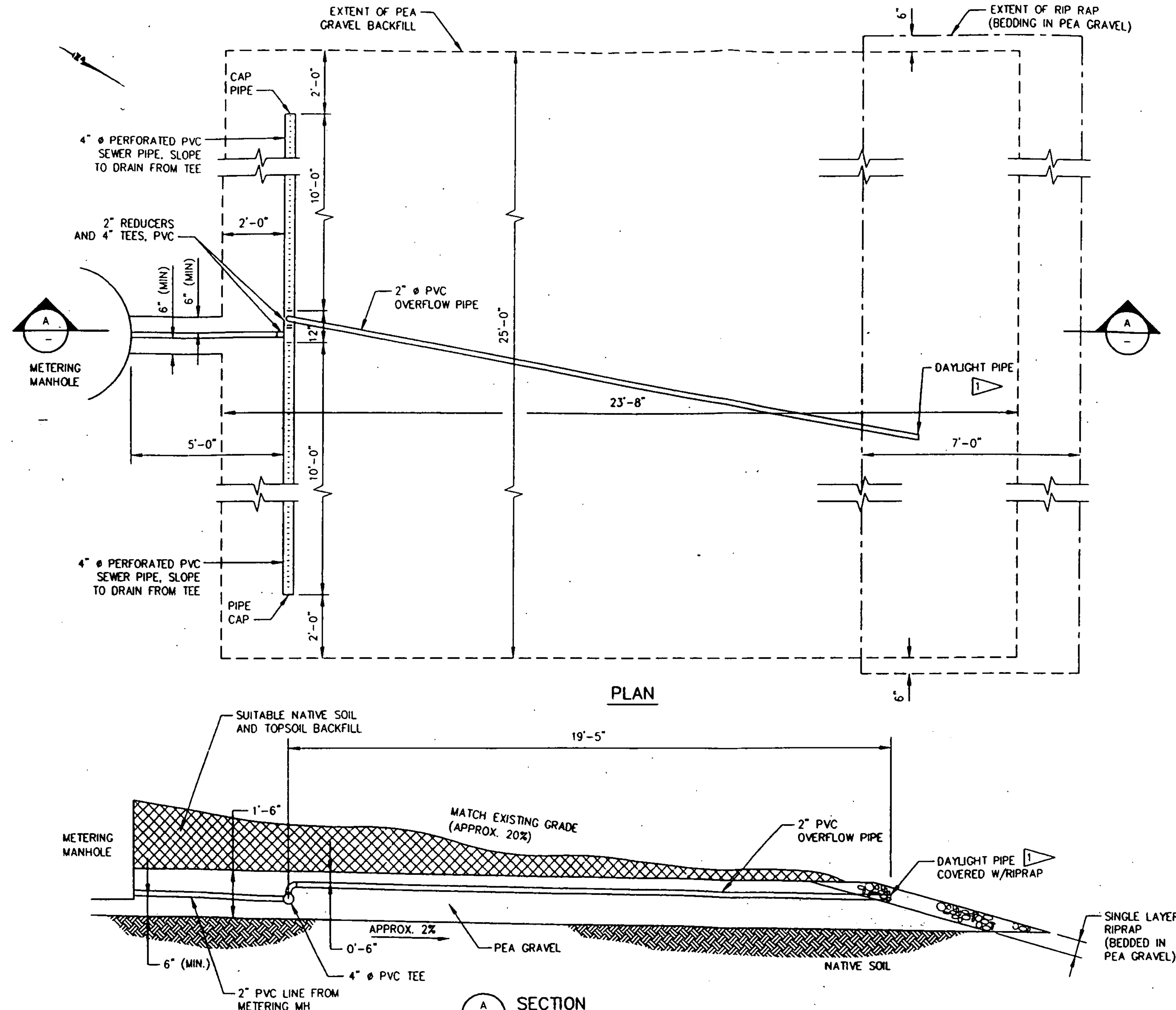
NOT TO SCALE




SEE SPECS. FOR COMPACTION AND MATERIAL REQUIREMENTS

2 CONVEYANCE PIPE BEDDING DETAILS FROM SUMP TO TREATMENT CELLS

NOT TO SCALE




3 FRENCH DRAIN DETAIL
0105

SCALE: 1/2" = 1'-0"

NOTES:

1. BED DAYLIGHTED PIPE WITH PEA GRAVEL.
2. PROVIDE HYDRATED BENTONITE SEAL BETWEEN PVC RISER PIPE AND SURFACE CASING, AND A MINIMUM 2" THICKNESS AROUND EXTERIOR OF CASING AS SHOWN.

| | | | |
|---|---|---|---|
| A (ISSUE) | AS BUILT (DESCRIPTION) | | CK3500E2 PROJECT/WCF NO. |
| KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons; DESIGNED BY FRIESEN KAF 12/17/99; DRAWN BY HEALY JH 12/17/99; CHECKED BY PARMAR 1/4/00; APPROVED BY WILKINSON 1/4/2000 | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO; Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| BLDG./FACILITY Site | REMOVE BURRS AND SHARP EDGES | | EAST TRENCHES PLUME TREATMENT SYSTEM; TRENCH, CLEANOUT, FRENCH DRAIN AND PIPE BEDDING DETAILS |
| ROOM/AREA N/A | NEXT ASSEMBLY N/A | CLASSIFIER CEX-012-96 | SIZE D |
| GRID COORD./COL NO. N/A | SCALE AS NOTED | LANDLORD PRIMROSE | DRAWING NUMBER 51615-0108 ISSUE A |

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

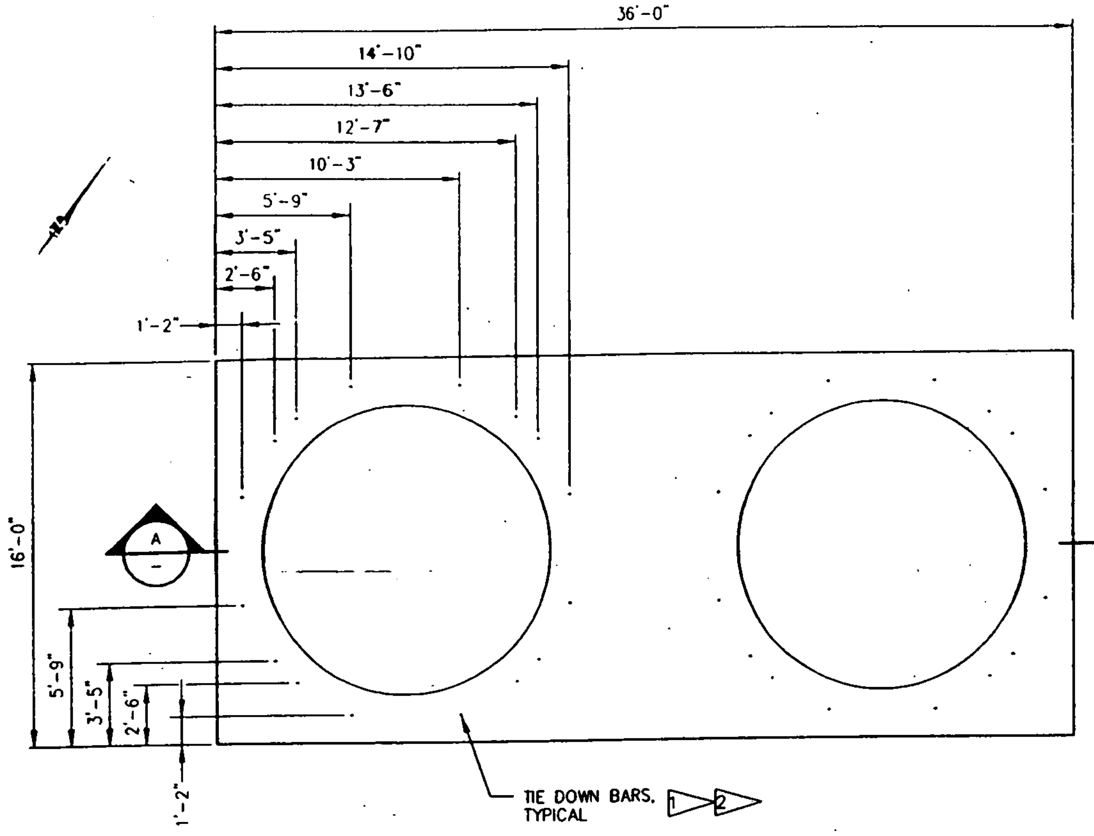
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

31

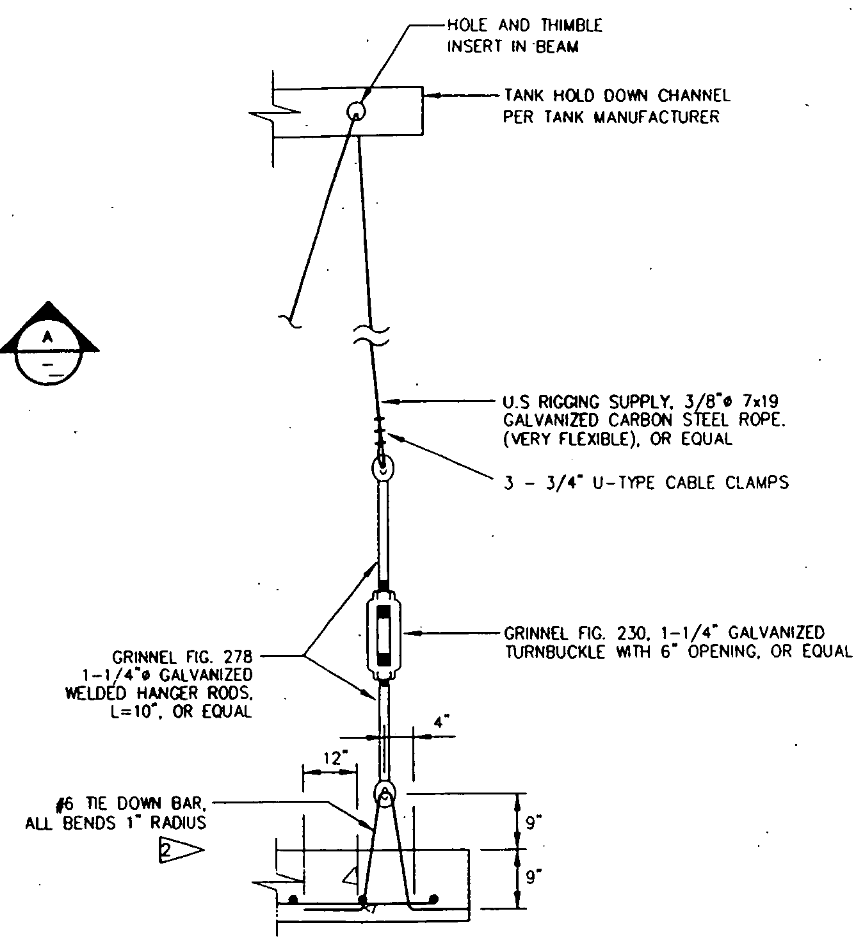
| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

STRUCTURAL NOTES:

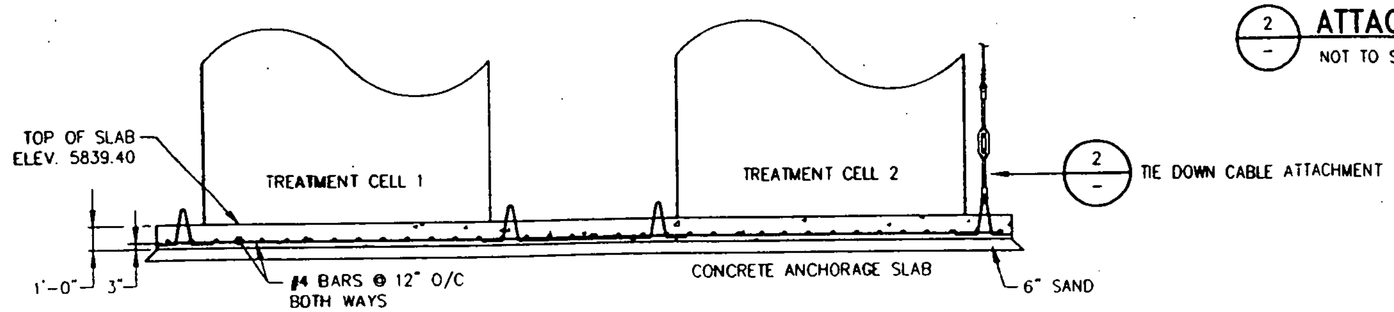
1. FIELD VERIFY LOCATIONS BASED ON DIMENSIONS OF CHANNEL FRAME ATTACHED TO TREATMENT CELLS.
2. ATTACH EYE BARS TO TIE DOWN BARS BEFORE POURING CONCRETE.




PLAN




2 TIE DOWN CABLE ATTACHMENT DETAIL
NOT TO SCALE




A SECTION

1 TREATMENT SYSTEM ANCHORAGE SLAB

4' 0 4'
SCALE: 1/4"=1'-0"

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1. Contamination; 2. Groundwater; 3. Remedial; 4. Treatment; 5. Trench |
| TOLERANCES | FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE |
| REMOVE BURRS AND SHARP EDGES | |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL NO | N/A |
| NEXT ASSEMBLY | N/A |
| SCALE: | AS NOTED |
| DESIGN COMPANY: | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 11/17/99 |
| DRAWN BY | HEALY JH 11/17/99 |
| CHECKED BY | STENSON 1/4/2000 |
| APPROVED BY | WILKINSON 1/4/2000 |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | CK3500E2 |

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO

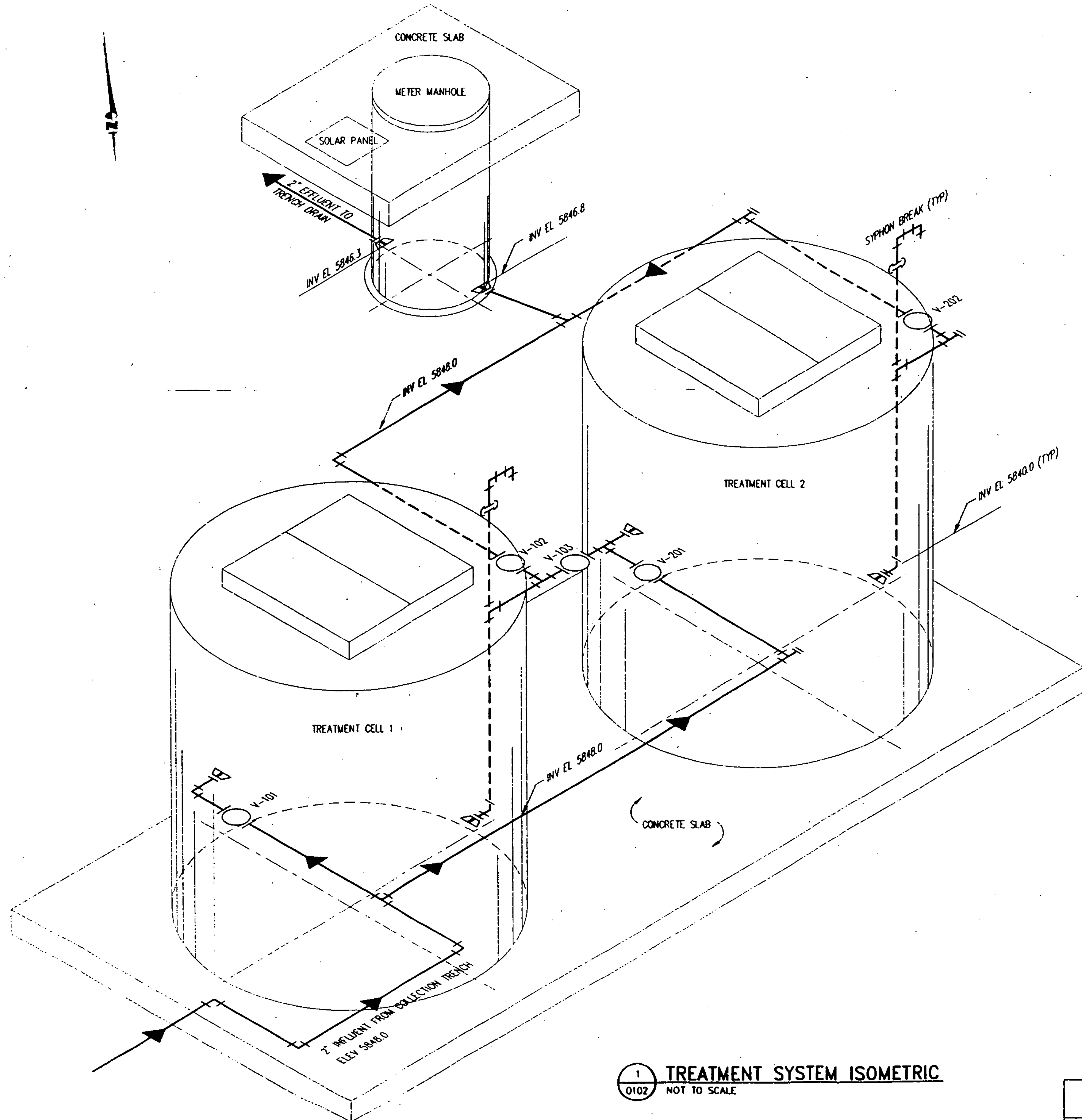
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

EAST TRENCHES PLUME TREATMENT SYSTEM

TREATMENT SYSTEM PAD AND STRUCTURAL DETAILS

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0201 | A |

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|




LEGEND

- PIPE AND DIRECTION OF FLOW
- BALL VALVE
- STRAIGHT TEE
- 90° ELBOW
- UNION (REMOVABLE)
- CAP (FOR FUTURE PIPING CONNECTION)
- FLANGED, GASKETED, AND BOLTED CONNECTION

(1 / 0102) TREATMENT SYSTEM ISOMETRIC
NOT TO SCALE

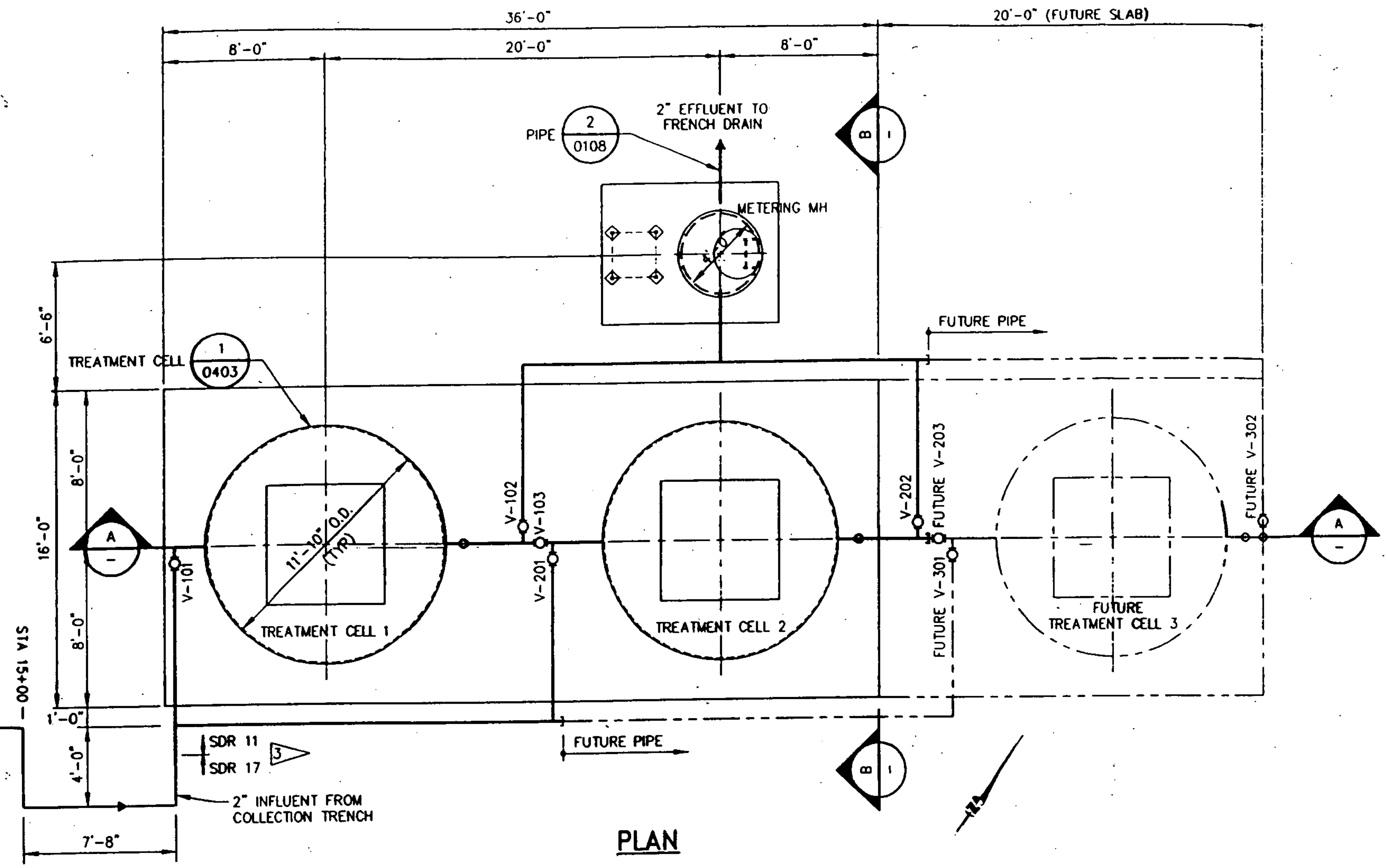
OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

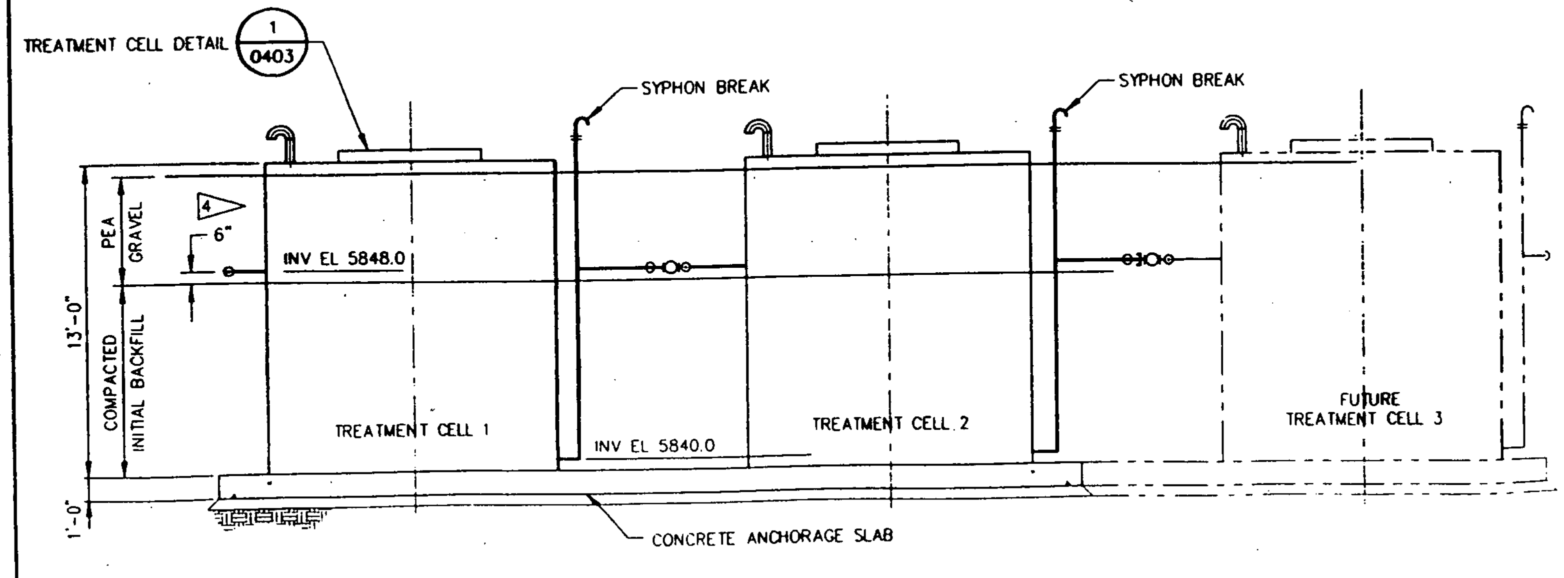
| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| PROJECT/WCF NO. | CK3500E2 |
| KEYWORDS | 1. Contamination; 2. Groundwater; 3. Remedial; 4. Treatment; 5. Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| TOLERANCES | FRACT. ±; ANGLE ±; DEC. ±; UNLESS NOTED OTHERWISE |
| REMOVE BURRS AND SHARP EDGES | |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN, KAF, 11/17/99 |
| DRAWN BY | HEALY, JH, 11/17/99 |
| CHECKED BY | STENSON, 1/4/2000 |
| APPROVED BY | WILKINSON, 1/4/2000 |
| CLASSIFIER | CEX-012-96 |
| LANDLORD | PRIMROSE |
| | U.S. DEPARTMENT OF ENERGY, ROCKY FLATS OFFICE, GOLDEN, COLORADO |
| | Rocky Flats Environmental Technology Site, GOLDEN, COLORADO |
| | EAST TRENCHES PLUME TREATMENT SYSTEM |
| | TREATMENT SYSTEM ISOMETRIC |
| SIZE | D |
| DRAWING NUMBER | 51615-0401 |
| ISSUE | A |

AUTOCAD COMPUTER GENERATED R\ACO\51615\0401\A

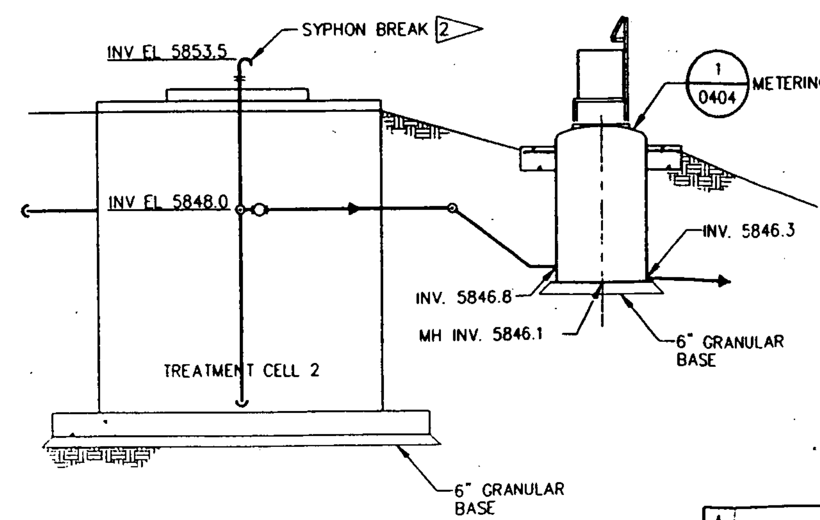
33




PLAN




A SECTION




B SECTION

SCALE: 1/4"=1'-0"

1 0105 TREATMENT SYSTEM PLAN

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

**TREATMENT CELL OPERATING MODES**

| Operating Modes | INITIAL VALVES: Cell 1 Inlet V-101 | Cell 1 Outlet V-102 | Transfer Valve V-103 | Cell 2 Inlet V-201 | Cell 2 Outlet V-202 | FUTURE VALVES: Transfer Valve V-203 | Cell 3 Inlet V-301 | Cell 3 Outlet V-302 |
|---|---|---|---|---|---|---|---|---|
| Cell 1 Only | OPEN | OPEN | CLOSED | CLOSED | CLOSED | CLOSED | CLOSED | CLOSED |
| Cell 2 Only | CLOSED | CLOSED | CLOSED | OPEN | OPEN | CLOSED | CLOSED | CLOSED |
| Cell 1 & 2 in Series | OPEN | CLOSED | OPEN | CLOSED | OPEN | CLOSED | CLOSED | CLOSED |
| Cell 1 & 2 in Parallel | OPEN | OPEN | CLOSED | OPEN | OPEN | CLOSED | CLOSED | CLOSED |
| Cell 3 Only | CLOSED | CLOSED | CLOSED | CLOSED | CLOSED | CLOSED | OPEN | OPEN |
| Cell 1, 2, & 3 in Series | OPEN | CLOSED | OPEN | CLOSED | CLOSED | OPEN | CLOSED | OPEN |
| Cell 1, 2, &3 in Parallel | OPEN | OPEN | CLOSED | OPEN | OPEN | CLOSED | OPEN | OPEN |
| Cell 2 & 3 in Series | CLOSED | CLOSED | CLOSED | OPEN | CLOSED | OPEN | CLOSED | OPEN |
| Cell 2 & 3 in Parallel | CLOSED | CLOSED | CLOSED | OPEN | OPEN | CLOSED | OPEN | OPEN |

NOTES

1. TREATMENT CELL HATCH, HOLD DOWN FRAME AND HANDRAIL NOT SHOWN FOR CLARITY. FOR DETAILS SEE SHEET 0403.
2. INSTALL UNION ON SYPHON BREAK TO ALLOW ACCESS FOR SAMPLING EFFLUENT FROM EACH TREATMENT CELL.
3. USE SDR II FOR PIPING TO TREATMENT CELLS AND METERING MANHOLE.
4. PLACE COMPACTED INITIAL BACKFILL UP TO 6 INCHES BELOW EACH VALVE.

LEGEND

- CAP
- BALL VALVE
- 90° BEND RUN OUT OF DRAWING PLANE
- TEE RUN INTO DRAWING PLANE
- TEE RUN OUT OF DRAWING PLANE
- UNION

OHM Energy Services Corporation
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver Colorado (303) 831-8100

| ISSUE | DESCRIPTION | |
|---|---|---|
| A | AS BUILT | |

KEYWORDS
1. Contamination
2. Groundwater
3. Remedial
4. Treatment
5. Trench

BLDG./FACILITY: Site
ROOM/AREA: N/A
GRID COORD./COL. NO.: N/A
TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE
REMOVE BURRS AND SHARP EDGES
NOT ASSEMBLY: N/A
SCALE: AS NOTED

DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN — KAF 11/17/99
DRAWN BY: HEALY — JH 11/17/99
CHECKED BY: STENSON
APPROVED BY: WILKINSON
CLASSIFIER: CEX-012-96
LANDLORD: PRIMROSE

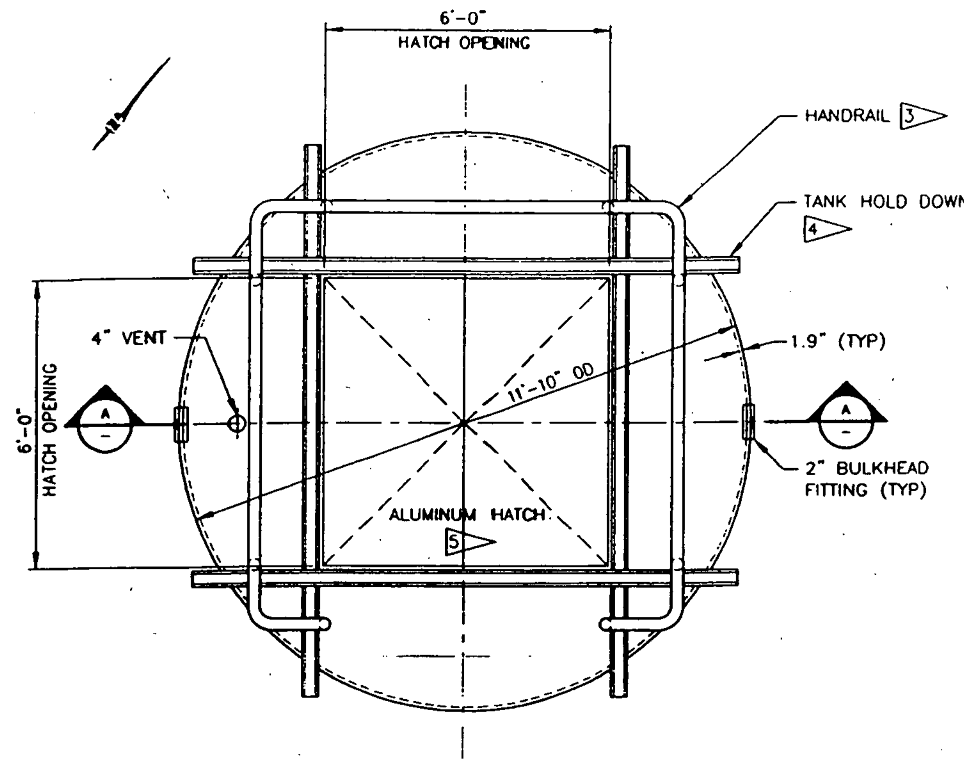
CK3500E2
PROJECT/WCF NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

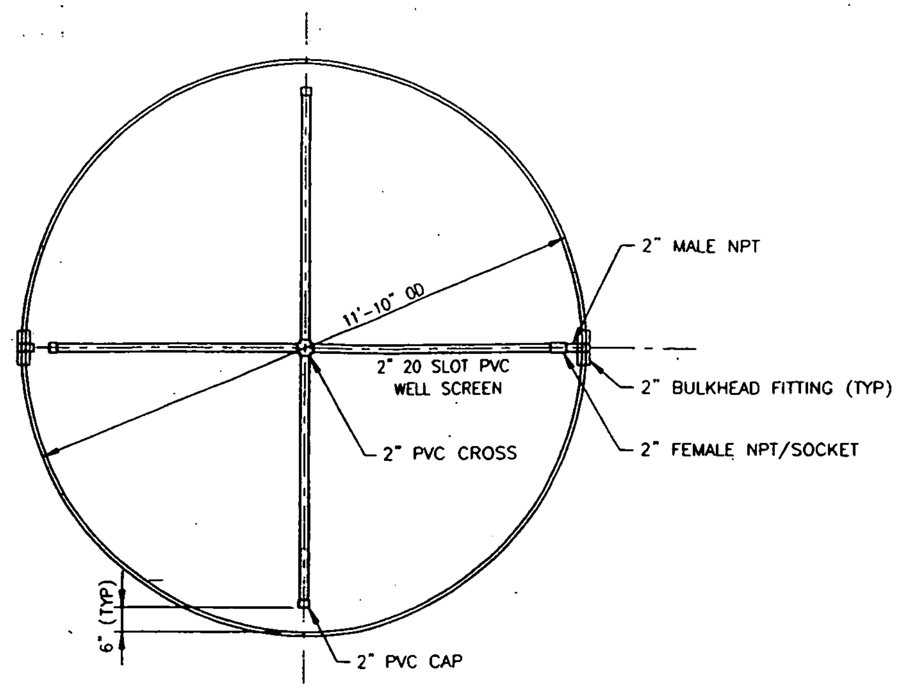
EAST TRENCHES PLUME TREATMENT SYSTEM
TREATMENT SYSTEM PLAN & SECTIONS

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0402 | A |

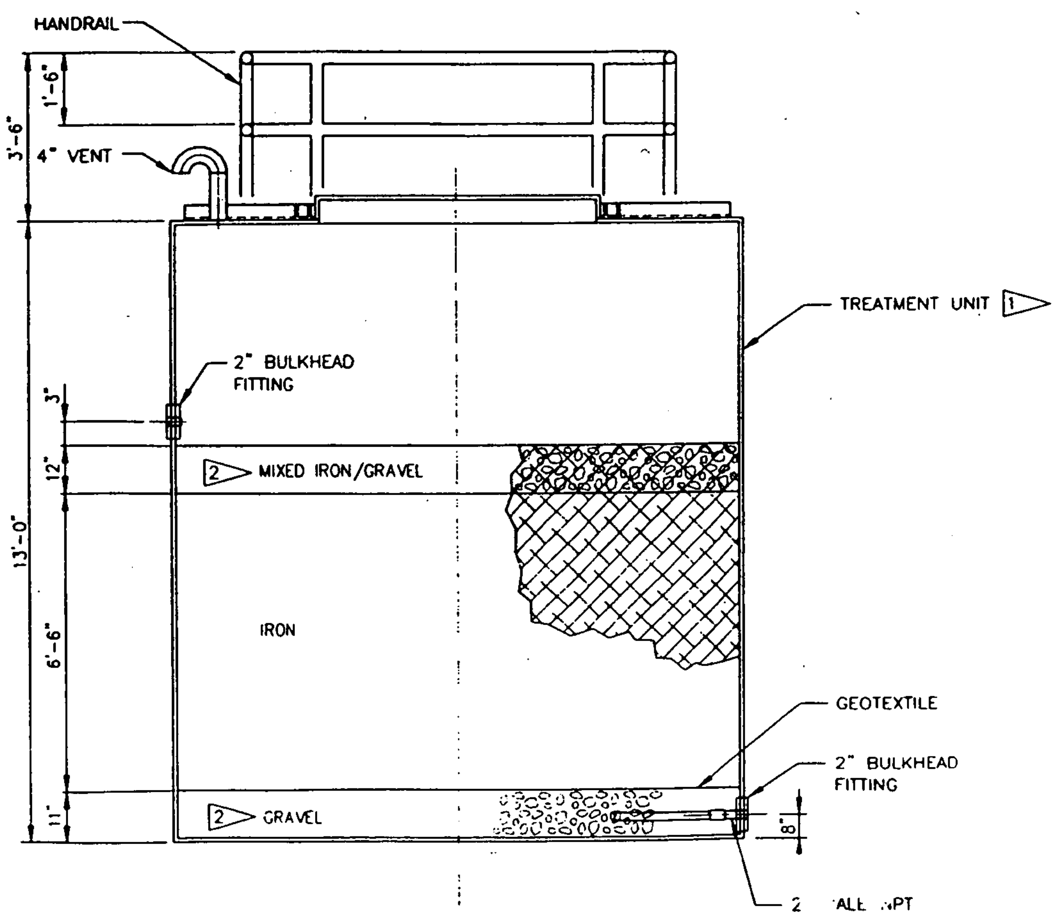
34



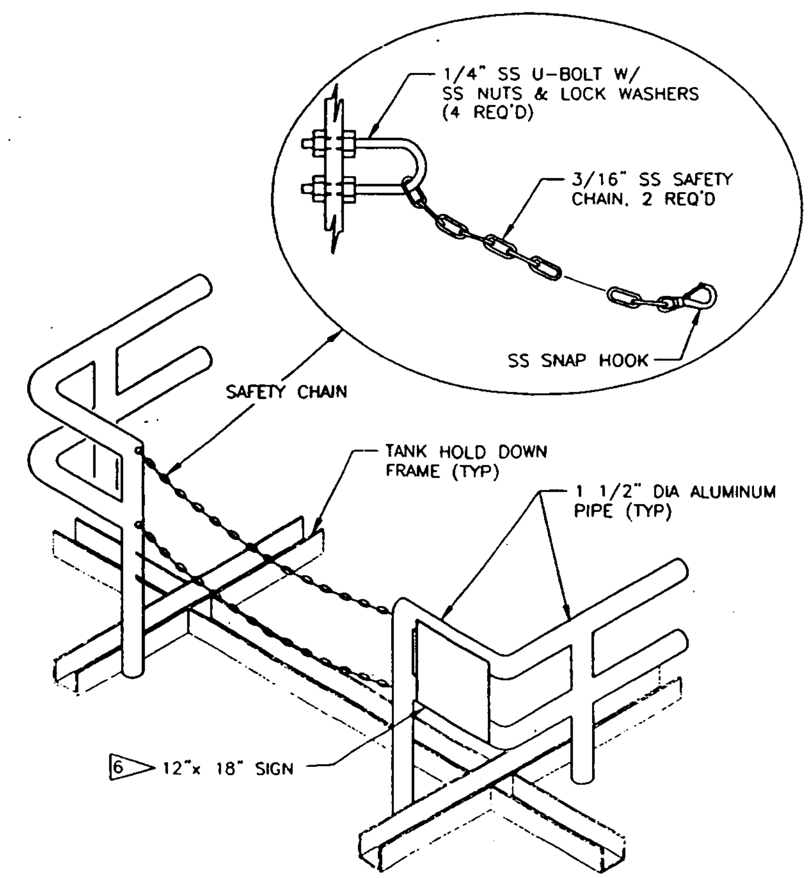

PLAN - TANK COVER




PLAN - OUTLET PIPING




A SECTION
NO SCALE




HANDRAIL DETAIL
NO SCALE

1 / 0402 TREATMENT CELL DETAIL

SCALE: 1/2"=1'-0"

NOTES

1. TREATMENT UNIT CONSTRUCTED OF PREFORMED HDPE.
2. TOP ONE FOOT OF MEDIA SHALL BE A MIXTURE OF 50% PEA GRAVEL AND 50% IRON MEDIA. THE PEA GRAVEL [illegible] MEET THE GRADATION REQUIREMENTS OF CLASS "C" MATERIAL IN THE STATE OF COLORADO, STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION.
3. HANDRAIL- 1 1/2" DIA ALUMINUM PIPE OR APPROVED ALTERNATE. SHOP FABRICATED. REMOVE ALL SHARP EDGES AFTER WELDING AND CUTTING. BOLT TO TANK HOLD DOWN FRAME WITH 1/2"DIA BOLTS, NUTS, & LOCK WASHERS. PAINT ANSI YELLOW.
4. TANK HOLD DOWN FRAME PER TANK MANUFACTURER PAINT ANSI YELLOW.
5. ALUMINUM HATCH- 6'-0"x 6'-0" CLEAR OPENING. DOUBLE LEAF, LOCKING, WATERTIGHT COVERS. COORDINATE WITH TANK MANUFACTURER TO ENSURE COMPATIBILITY WITH TANK HOLD DOWN FRAME.
6. 1/8-INCH THICK STEEL. ATTACH TO HANDRAIL. PAINT WHITE WITH BLACK STENCIL LETTERS 2" MIN. HIGH. SIGN TO READ "CONFINED SPACE ENTRY PERMIT REQUIRED FOR ENTRY".

OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver Colorado (303) 831-8100

| ISSUE | DESCRIPTION | |
|---|---|---|
| A | AS BUILT | |

KEYWORDS: 1. Contamination; 2. Groundwater; 3. Remedial; 4. Treatment; 5. Trench

BLDG./FACILITY: Site
ROOM/AREA: N/A
GRID COORD./COL NO: N/A
NEXT ASSEMBLY: N/A
SCALE: AS NOTED

DESIGN COMPANY: OHM/Parsons

| | NAME | INITIALS | DATE |
|---|---|---|---|
| DESIGNED BY | FRIESEN | KAF | 11/17/99 |
| DRAWN BY | HEALY | JH | 11/17/99 |
| CHECKED BY | STENSON | | |
| APPROVED BY | WILKINSON | | |

CLASSIFIER: CEX-012-96
LANDLORD: PRIMROSE

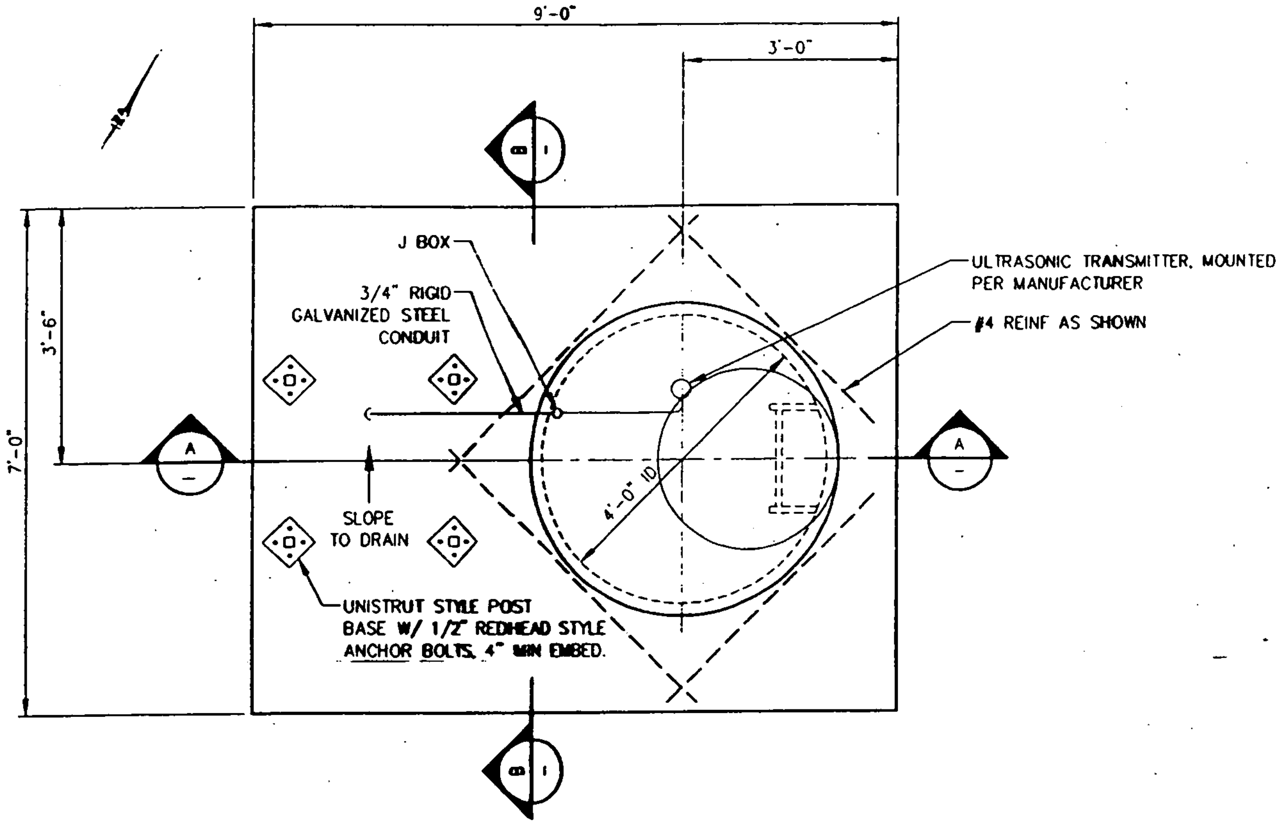
CK3500E2
PROJECT/WCF NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

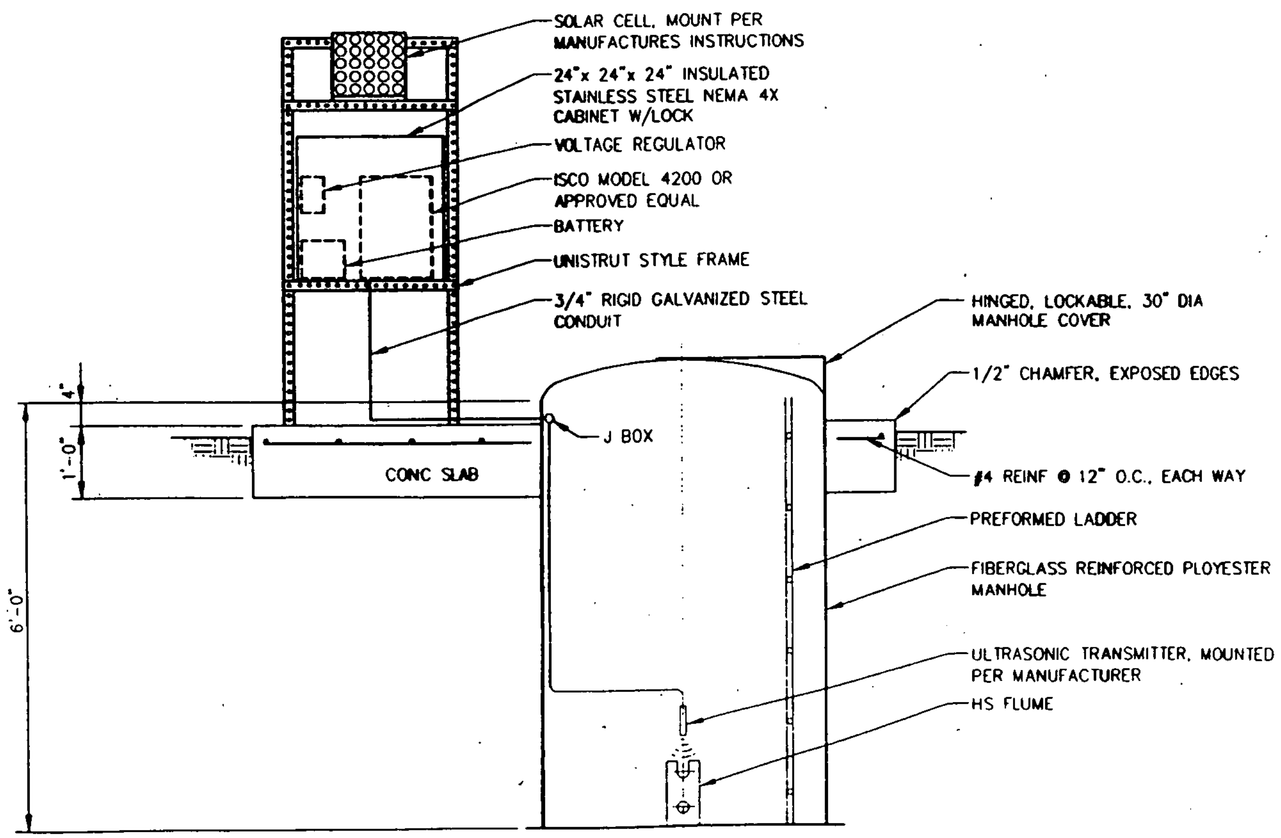
EAST TRENCHES PLUME TREATMENT SYSTEM
TREATMENT CELL PLAN, SECTIONS & DETAILS

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51615-0403 | A |

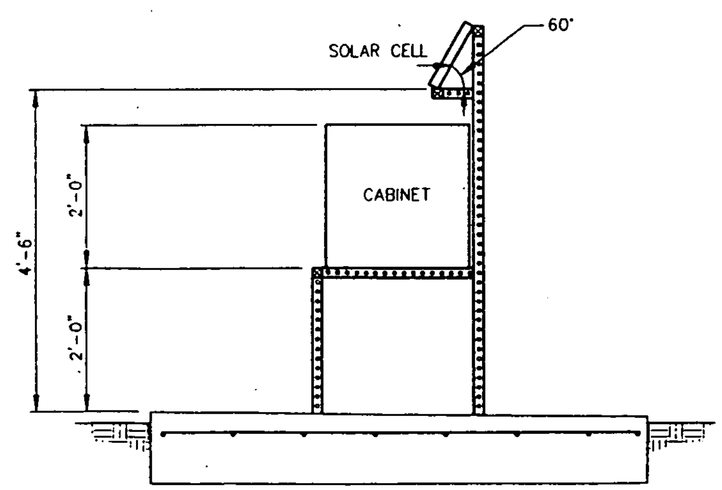
35




PLAN – TANK COVER




A SECTION




B SECTION

1 / 0105 METER MH DETAIL

NO SCALE

SCALE: 3/4"=1'-0"

| | | | |
|---|---|---|---|
| A ISSUE | AS BUILT DESCRIPTION | | CK3500E2 PROJECT/WCF NO. |
| KEYWORDS: 1. Contamination 2. Groundwater 3. Remedial 4. Treatment 5. Trench | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO |
| | | DESIGNED BY: FRIESEN KAF 11/17/99 | Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| | | DRAWN BY: HEALY JH 11/17/99 | |
| | | CHECKED BY: STENSON | EAST TRENCHES PLUME TREATMENT SYSTEM |
| | REMOVE BURRS AND SHARP EDGES | APPROVED BY: WILKINSON | METERING MANHOLE PLAN, SECTIONS & DETAILS |
| BLDG./FACILITY: Site | NEXT ASSEMBLY: N/A | CLASSIFIER: CEX-012-96 | SIZE: D |
| ROOM/AREA: N/A | SCALE: AS NOTED | LANDLORD: PRIMROSE | DRAWING NUMBER: 51615-0404 |
| GRID COORD./COL NO: N/A | | | ISSUE: A |

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver Colorado (303) 831-8100

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

36

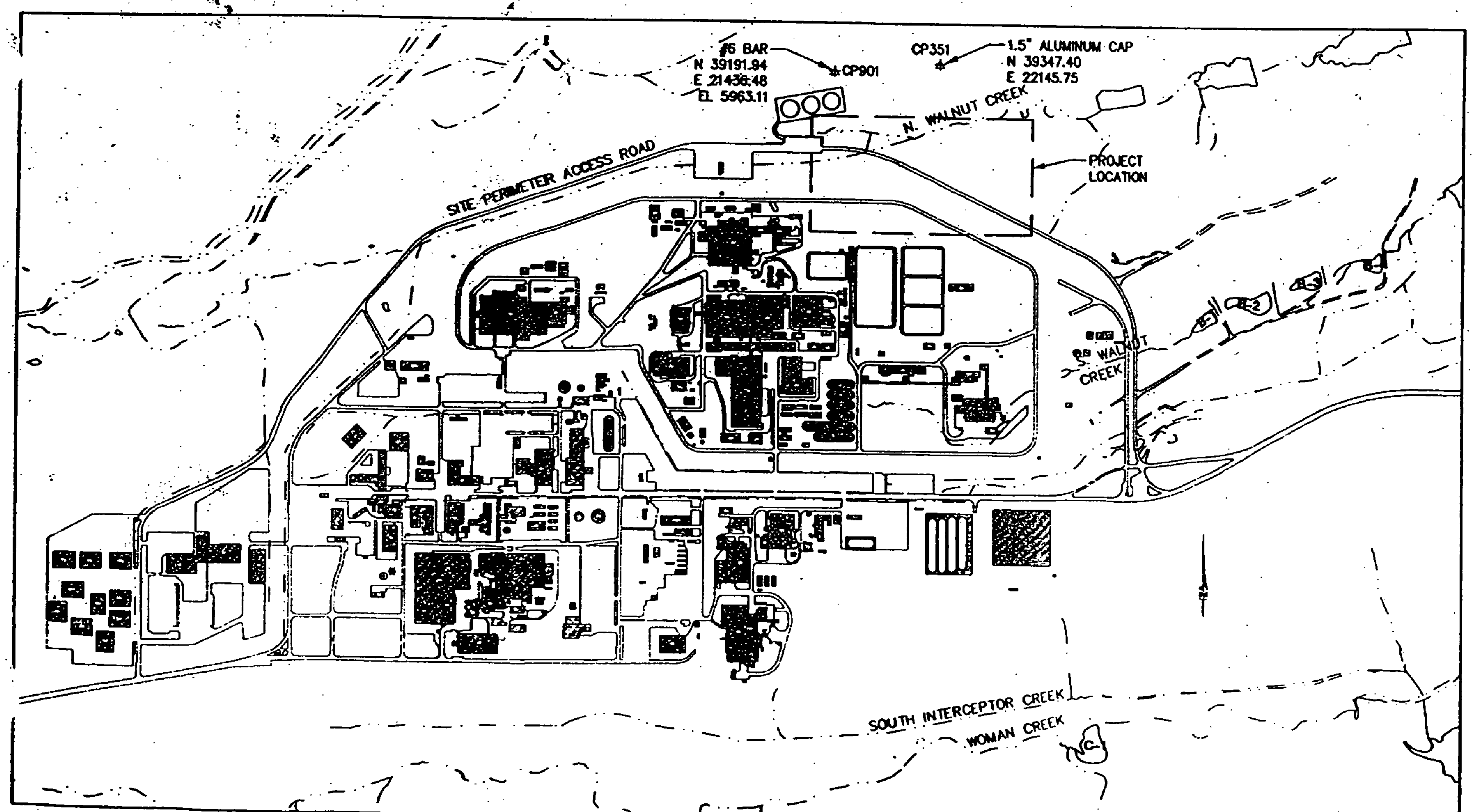
# Solar Ponds Plume Treatment System As-Builts

AS BUILT DRAWINGS

# SOLAR PONDS PLUME TREATMENT SYSTEM

## ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE, GOLDEN, COLORADO

JANUARY, 2000



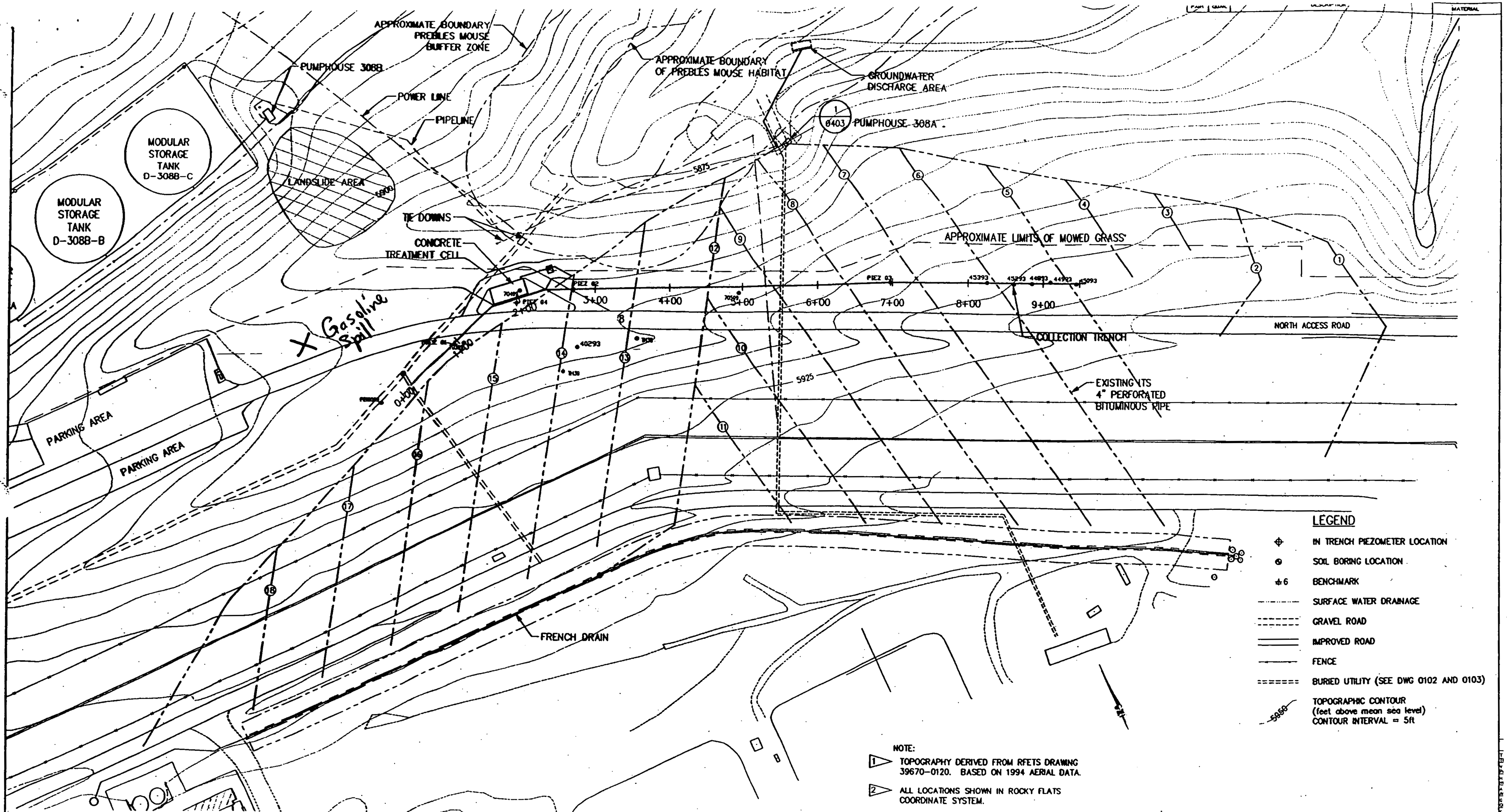

PROJECT LOCATION

LEGEND



OHM Energy Services Corporation
A Subsidiary of OHM Corporation

| | | | | |
|---|---|---|---|---|
| A ISSUE | AS BUILT DESCRIPTION | | | T0099204 PROJECT/WCF NO. |
| KEYWORDS | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons | | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO |
| 1.Contamination | | DESIGNED BY FRIESEN | KAF 10/26/99 | Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| 2.Groundwater | | DRAWN BY HEALY | JH 10/26/99 | |
| 3.Remedial | | CHECKED BY STENSON | 1/4/2000 | SOLAR PONDS PLUME TREATMENT SYSTEM |
| 4.Treatment | | APPROVED BY WILKINSON | 1/4/2000 | INDEX / TITLE SHEET AND PROJECT LOCATION |
| 5.Trench | REMOVE BURRS SHARP EDGES | | | |
| BLDG./FACILITY Site | NEXT ASSEMBLY | | | |




## LEGEND

- IN TRENCH PIEZOMETER LOCATION
- SOIL BORING LOCATION
- BENCHMARK
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- BURIED UTILITY (SEE DWG 0102 AND 0103)
- TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft

NOTE:

1. TOPOGRAPHY DERIVED FROM RFETS DRAWING 39670-0120. BASED ON 1994 AERIAL DATA.
2. ALL LOCATIONS SHOWN IN ROCKY FLATS COORDINATE SYSTEM.

COORDINATES FOR 1999 GEOTECHNICAL BORINGS 2

| Northing | Easting | Ground Elevation | Description |
|---|---|---|---|
| 38601.93 | 21670.66 | 5899.48 | DRILL HOLE (No. 1) 70399 |
| 38632.20 | 21764.99 | 5900.83 | DRILL HOLE (No. 2) 70499 |
| 38507.04 | 22030.69 | 5908.44 | DRILL HOLE (No. 3) 70599 |

SITE PLAN

60' 0 60'

SCALE: 1"=60'

OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

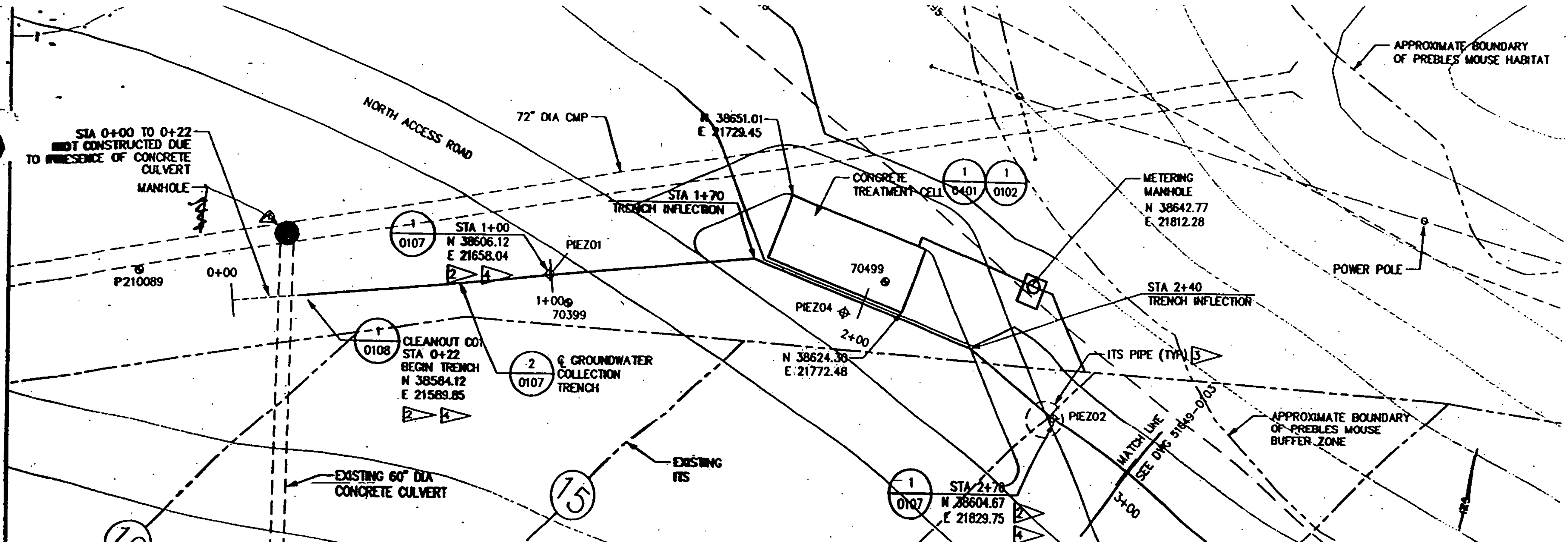
| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| SITE/FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| NEXT ASSEMBLY | N/A |
| SCALE: | AS NOTED |
| DESIGN COMPANY: | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 11/7/99 |
| DRAWN BY | HEALY JH 11/7/99 |
| CHECKED BY | STENSON 1/4/2000 |
| APPROVED BY | WILKINSON |
| CLASSIFIER | |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | T0099204 |

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO

Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

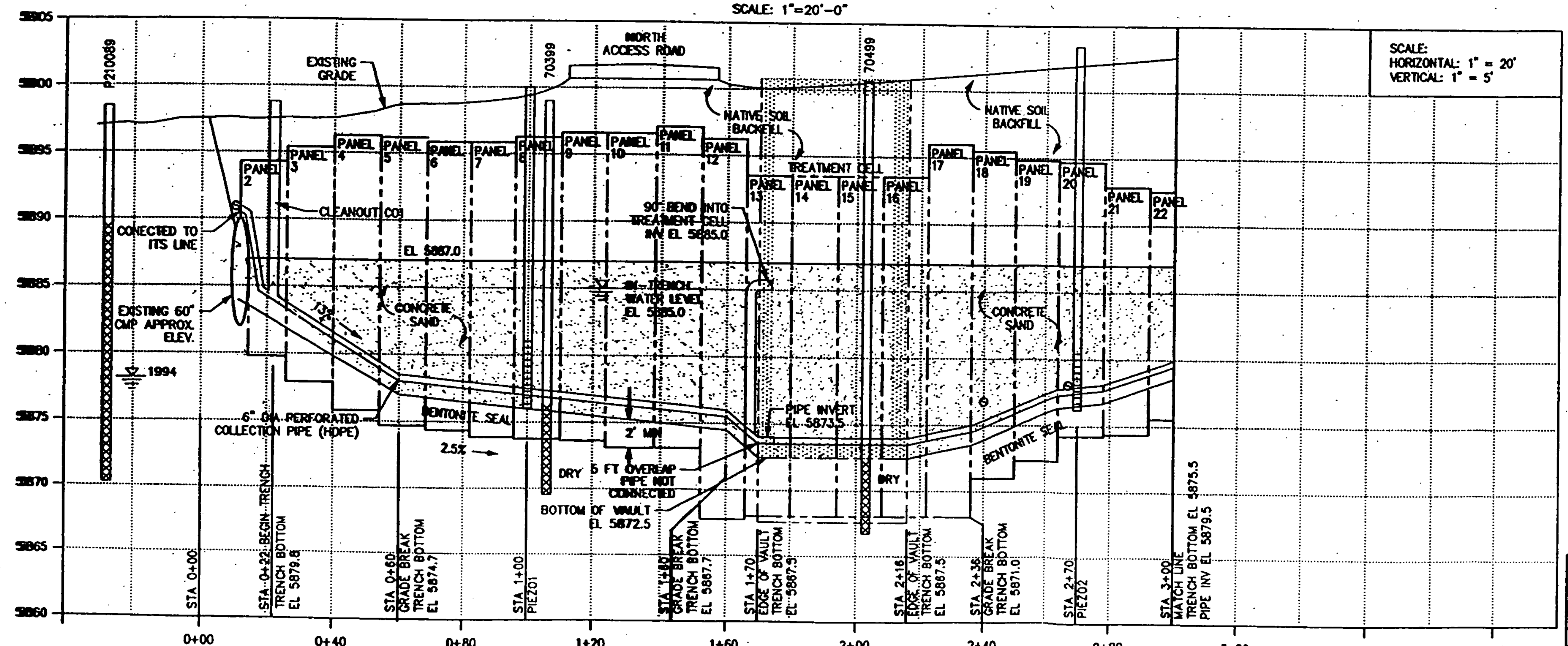
SOLAR PONDS PLUME TREATMENT SYSTEM
SITE PLAN

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0101 | A |




SITE PLAN

SCALE: 1"=20'-0"




GEOLOGIC PROFILE (FACING NORTHWEST)

## LEGEND

- IN TRENCH PIEZOMETER LOCATION
- SOIL BORING LOCATION
- BENCHMARK
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- EXISTING FENCE
- TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- ALLUVIUM / BEDROCK — BOREHOLE DATA
- GROUNDWATER LEVEL DURING YEAR SHOWN
- DRY — NO GROUNDWATER ENCOUNTERED AT TIME OF DRILLING
- PROJECTED ITS PIPE PENETRATION INTO COLLECTION TRENCH

NOTES:

1. DEPTH AND LOCATION OF ITS PIPE IS BASED ON FIELD OBSERVATION DURING CONSTRUCTION.
2. ALL LOCATIONS SHOWN IN ROCKY FLATS COORDINATES.
3. EXISTING ITS PIPE WITHIN COLLECTION TRENCH EXCAVATION REMOVED WITH EXCAVATION EQUIPMENT. UPGRADIENT PIPE DISCHARGES INTO CONCRETE SAND. ITS PIPE CUT 1 FOOT BEHIND DOWNGRADIENT WALL OF TRENCH AND BACKFILLED TO TRENCH SECTION TO PREVENT DAMAGE TO GEOMEMBRANE.
4. PIEZOMETER AND CLEANOUT ELEVATIONS: FEET ABOVE MEIN SEA LEVEL

70799
70899
70999
71099

| Point | Northing | Easting | Top of Concrete Pad | Top of Casing |
|---|---|---|---|---|
| PIEZ 01 | 38606.12 | 21658.04 | 5899.58 | 5901.07 |
| PIEZ 02 | 38604.67 | 21829.25 | 5899.85 | 5901.59 |
| PIEZ 03 | 38433.75 | 22219.66 | 5919.72 | 5920.72 |
| PIEZ 04 | 38619.85 | 21754.64 | 5900.71 | 5901.94 |
| C01 | 38584.12 | 21589.85 | 5897.22 | |
| C02 | 38471.07 | 22131.36 | 5913.29 | |
| C03 | 38323.34 | 22455.55 | 5928.71 | |

OHM Energy Services Corporation

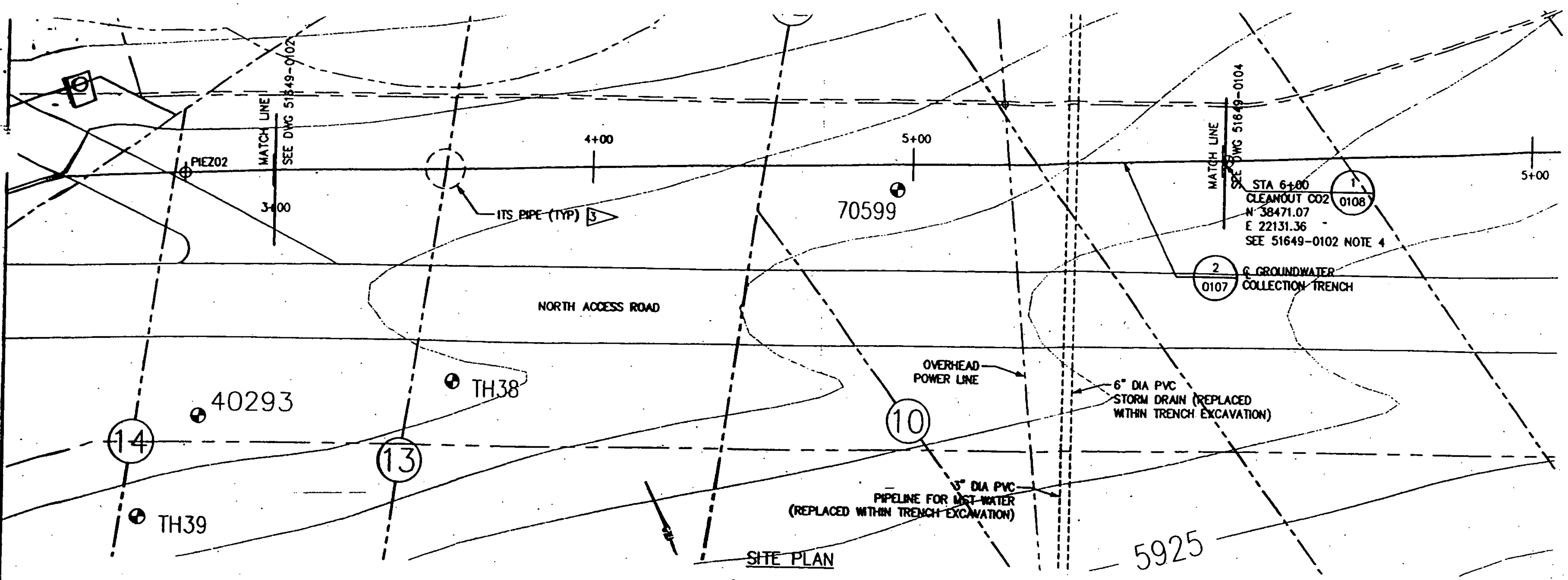
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A — AS BUILT |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| BLDG./FACILITY | Site |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 11/17/99 |
| DRAWN BY | HEALY JH 11/17/99 |
| CHECKED BY | STENSON |
| APPROVED BY | WILKINSON |
| SCALE | AS NOTED |
| CLASSIFIER | N/A |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | T0099204 |

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

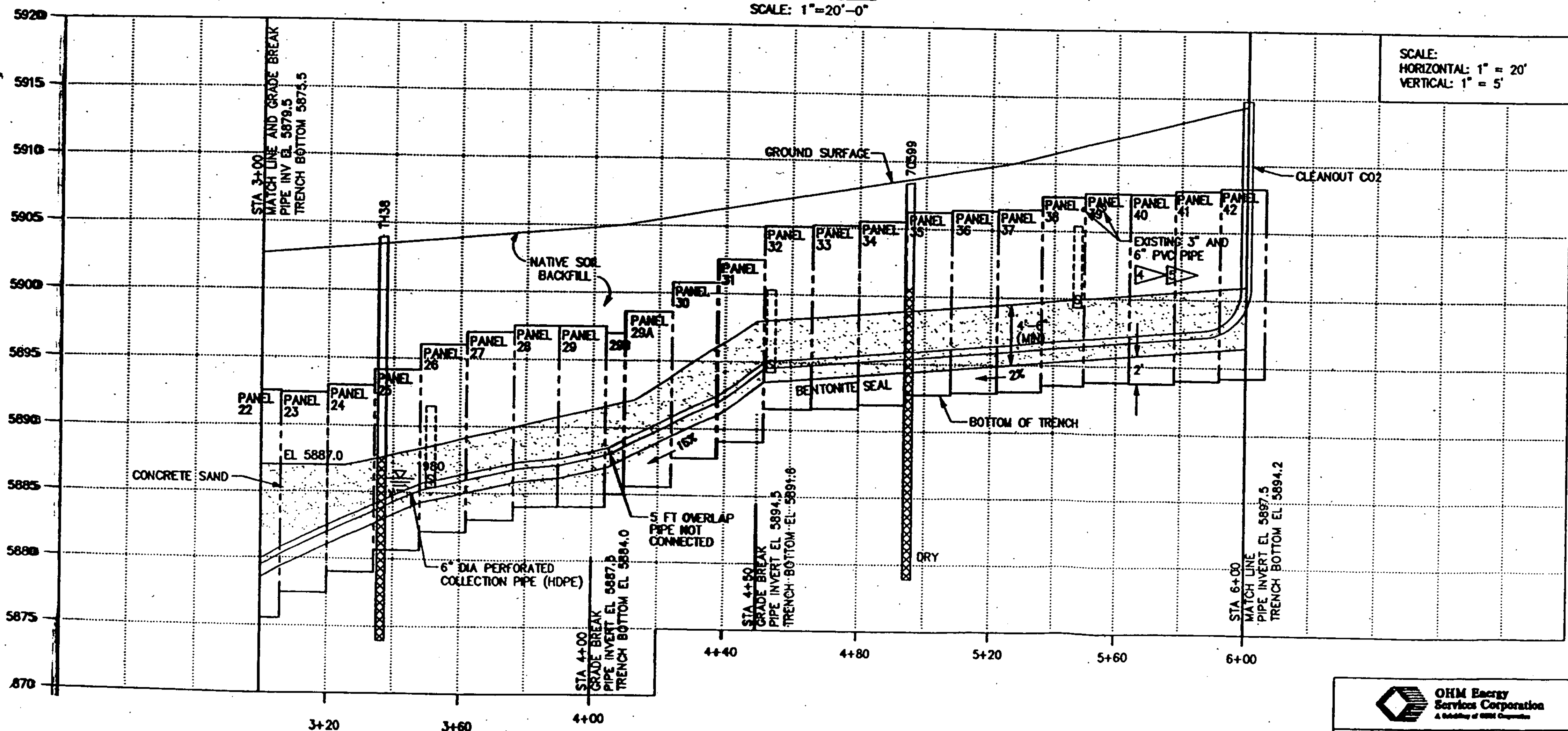
SOLAR PONDS PLUME TREATMENT SYSTEM
COLLECTION TRENCH PLAN & PROFILE
STA 0+00 TO 3+00

SIZE D | DRAWING NUMBER 51649-0102 | ISSUE A




SITE PLAN

20' 0 20'
SCALE: 1"=20'-0"




PROFILE (FACING NORTHEAST)

## LEGEND

- IN TRENCH PIEZOMETER LOCATION
- SOIL BORING LOCATION
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5950 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- (UNDIFFERENTIATED) ALLUVIUM / CLAYSTONE BEDROCK — BOREHOLE DATA
- 1994 GROUNDWATER LEVEL DURING YEAR SHOWN
- PROJECTED ITS PIPE PENETRATION INTO COLLECTION TRENCH AND GRAVEL BLANKET 1

NOTES:

1. DEPTH AND LOCATION OF ITS PIPE IS BASED ON FIELD OBSERVATIONS DURING CONSTRUCTION.
2. ALL LOCATIONS SHOWN IN ROCKY FLATS COORDINATES.
3. EXISTING ITS PIPE WITHIN COLLECTION TRENCH EXCAVATION REMOVED WITH EXCAVATION EQUIPMENT. UPGRADIENT PIPE DISCHARGES INTO CONCRETE SAND. ITS PIPE CUT 1 FOOT BEHIND DOWNGRADIENT WALL OF TRENCH AND BACKFILLED TO TRENCH SECTION TO PREVENT DAMAGE TO GEOMEMBRANE.
4. DEPTH, LOCATION AND SIZE OF BURIED PIPE IS ESTIMATED.
5. SEALING OF GEOMEMBRANE AROUND EXISTING PIPES NOT REQUIRED.

OHM Energy Services Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| ISSUE | DESCRIPTION |
|---|---|
| A | AS BUILT |

KEYWORDS
1. Contamination
2. Groundwater
3. Remedial
4. Treatment
5. Trench

Site: Site
N/A
N/A

| | | |
|---|---|---|
| DESIGN COMPANY: OHM/Parsons | | |
| DESIGNED BY: FRIESEN | KAF | 10/26/99 |
| DRAWN BY: HEALY | JH | 10/26/99 |
| CHECKED BY: STENSON | | |
| APPROVED BY: WILKINSON | | |

SCALE: AS NOTED
CLASSIFIER
LANDLORD: PRIMROSE

T0099204
PROJECT/WCF NO.

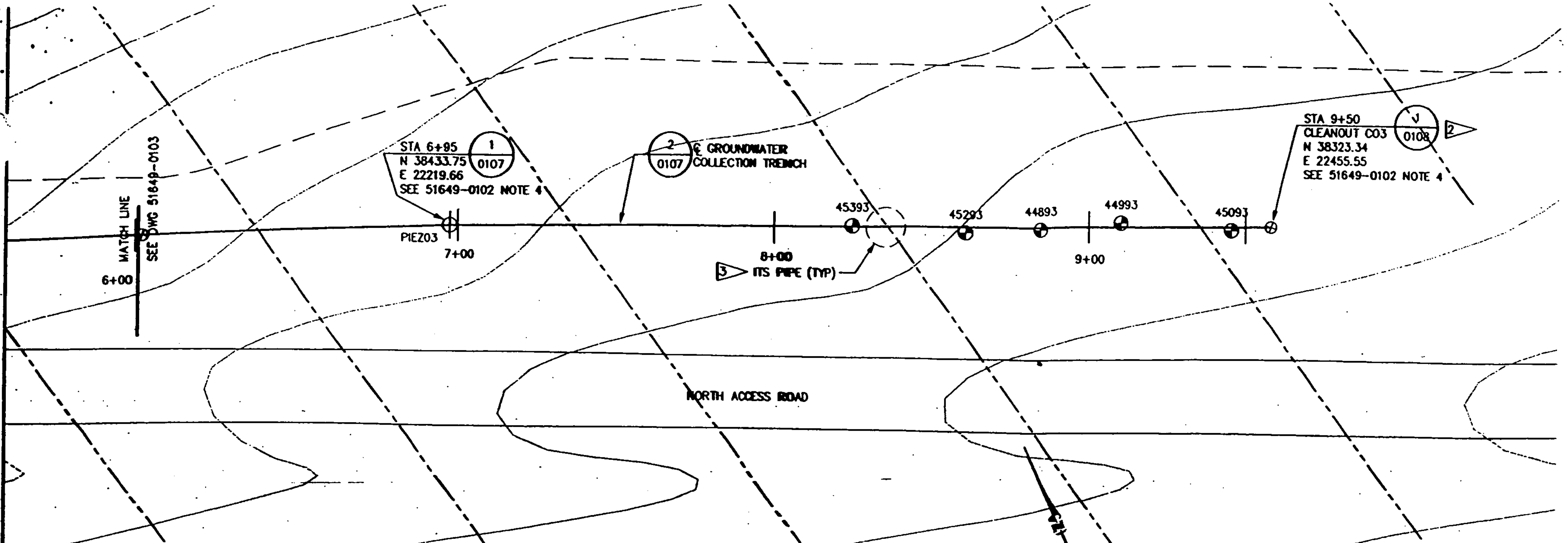
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

SOLAR PONDS PLUME TREATMENT SYSTEM

COLLECTION TRENCH PLAN & PROFILE STA 3+00 TO 6+00

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0103 | A |

41

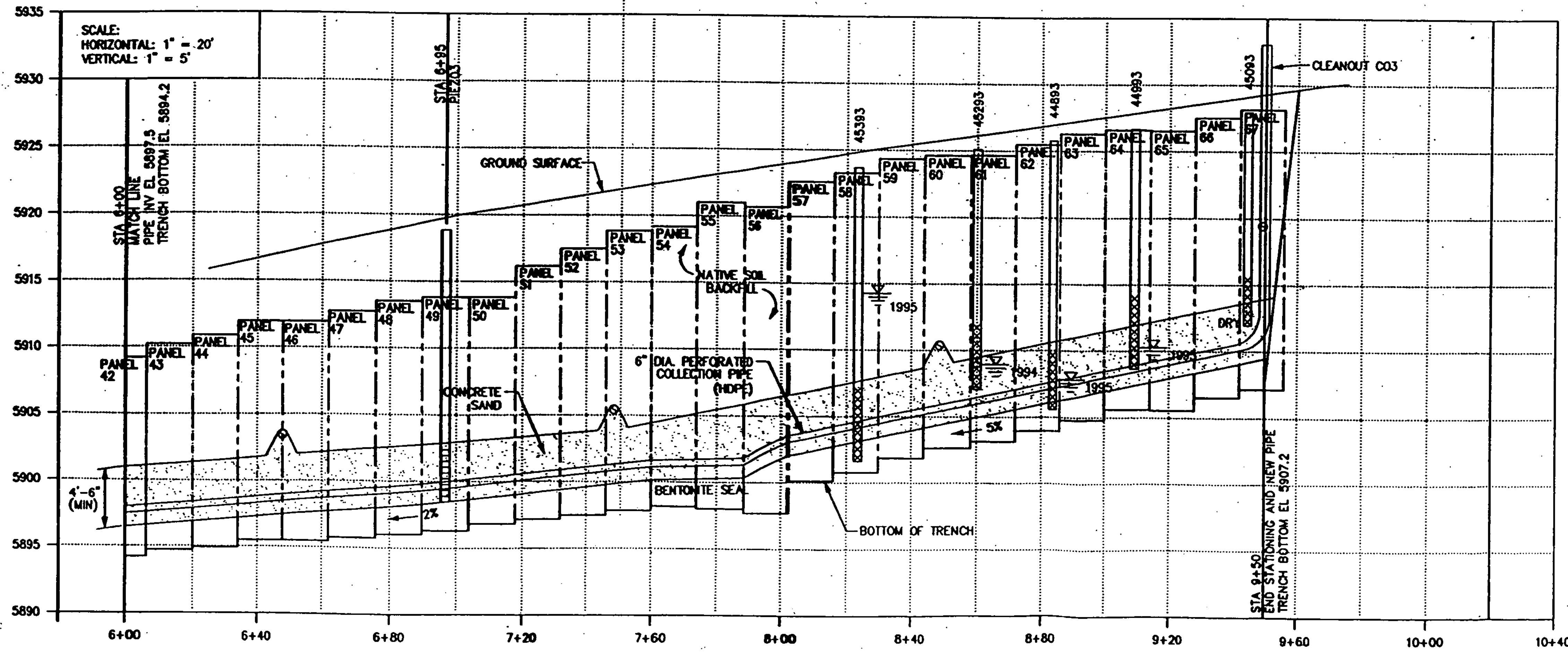



SITE PLAN

20' 0 20'
SCALE: 1"=20'-0"

## LEGEND

- IN TRENCH PIEZOMETER LOCATION
- SOIL BORING LOCATION
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5950 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft
- (UNDIFFERENTIATED) ALLUVIUM / CLAYSTONE BEDROCK — BOREHOLE DATA
- 1994 GROUNDWATER LEVEL DURING YEAR SHOWN
- PROJECTED ITS PIPE PENETRATION INTO COLLECTION TRENCH 1
- DRY — NO GROUNDWATER ENCOUNTERED AT TIME OF DRILLING




PROFILE (FACING NORTHEAST)

NOTES:

1. DEPTH AND LOCATION OF ITS PIPE IS BASED ON FIELD OBSERVATIONS DURING CONSTRUCTION.
2. ALL LOCATIONS SHOWN IN ROCKY FLATS COORDINATES.
3. EXISTING ITS PIPE WITHIN COLLECTION TRENCH EXCAVATION REMOVED DURING CONSTRUCTION. UPGRADIENT PIPE DISCHARGES INTO CONCRTE SAND. ITS PIPE CUT 1 FOOT BEHIND DOWNGRADIENT WALL OF TRENCH AND BACKFILLED TO TRENCH SECTION TO PREVENT DAMAGE TO GEOMEMBRANE.

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| PROJECT/WCF NO. | T0099204 |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| BUILDING/FACILITY | Site |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 10/26/99 |
| DRAWN BY | HEALY JH 10/26/99 |
| CHECKED BY | STENSON |
| APPROVED BY | WILKINSON |
| SCALE | AS NOTED |
| CLASSIFIER | PRIMROSE |
| SIZE | D |
| DRAWING NUMBER | 51649-0104 |

OHM Energy Services Corporation

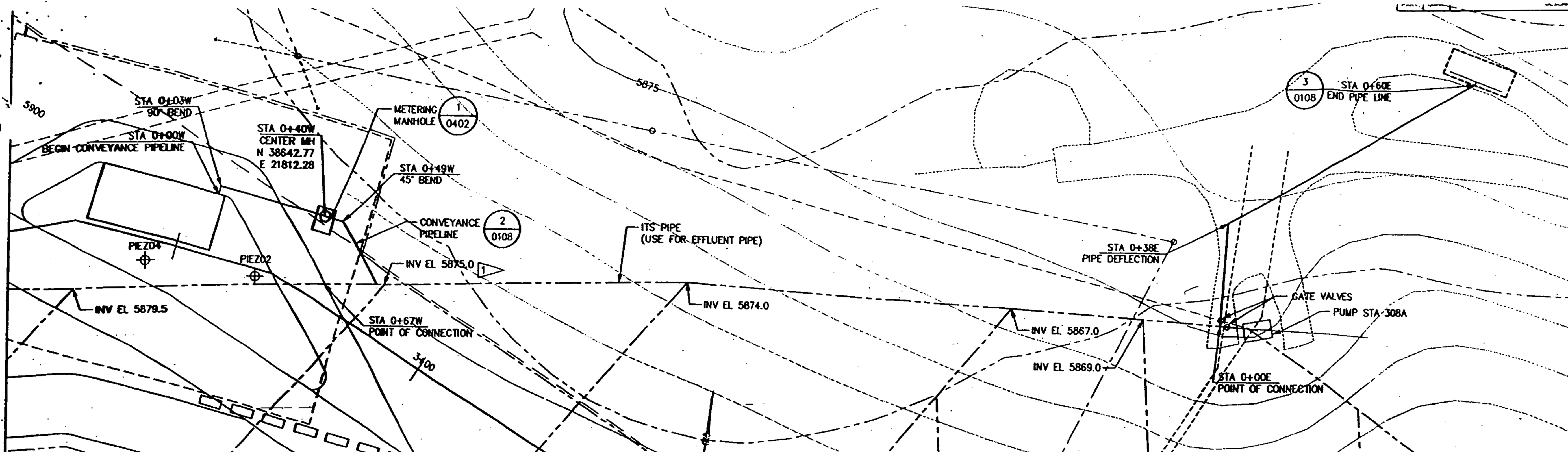
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

SOLAR PONDS PLUME TREATMENT SYSTEM
COLLECTION TRENCH PLAN & PROFILE
STA 6+00 TO 9+50

COMPUTER GENERATED R\ACD\51649\0104\A

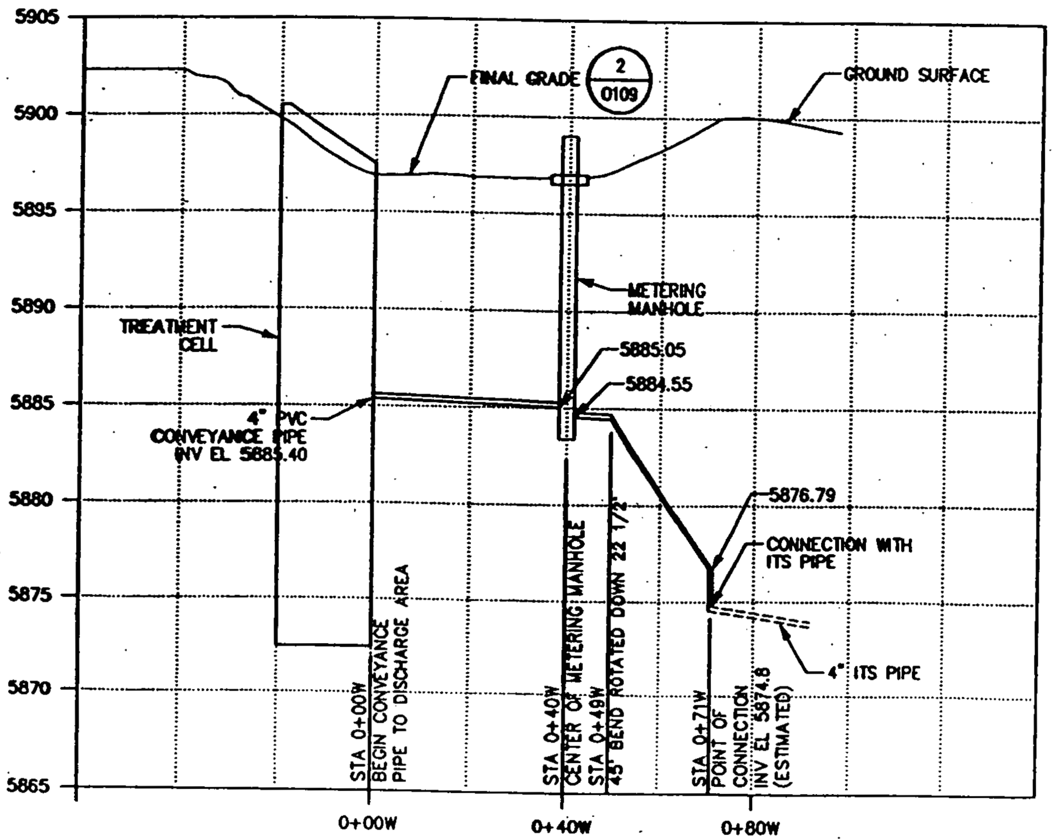
42



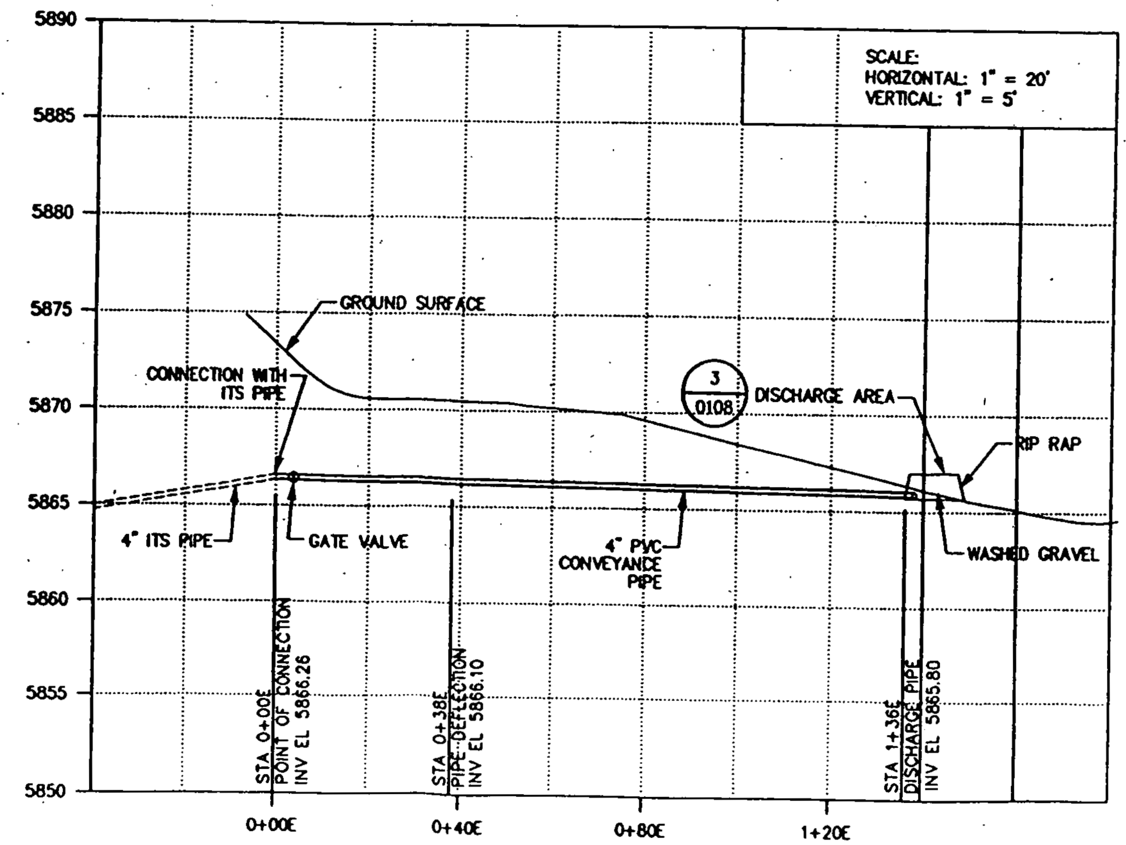

SITE PLAN

SCALE: 1"=20'-0"

1 AS-BUILT INVERT ELEVATION OF EXISTING ITS PIPE FROM RFETS DWG 27550-040.




WEST PROFILE




EAST PROFILE

## LEGEND

- IN TRENCH PIEZOMETER LOCATION
- SOIL BORING LOCATION
- 6 BENCHMARK
- SURFACE WATER DRAINAGE
- GRAVEL ROAD
- IMPROVED ROAD
- FENCE
- 5860 TOPOGRAPHIC CONTOUR (feet above mean sea level) CONTOUR INTERVAL = 5ft

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| ISSUE | DESCRIPTION | PROJECT/WCF NO. |
|---|---|---|
| A | AS BUILT | T0099204 |

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench

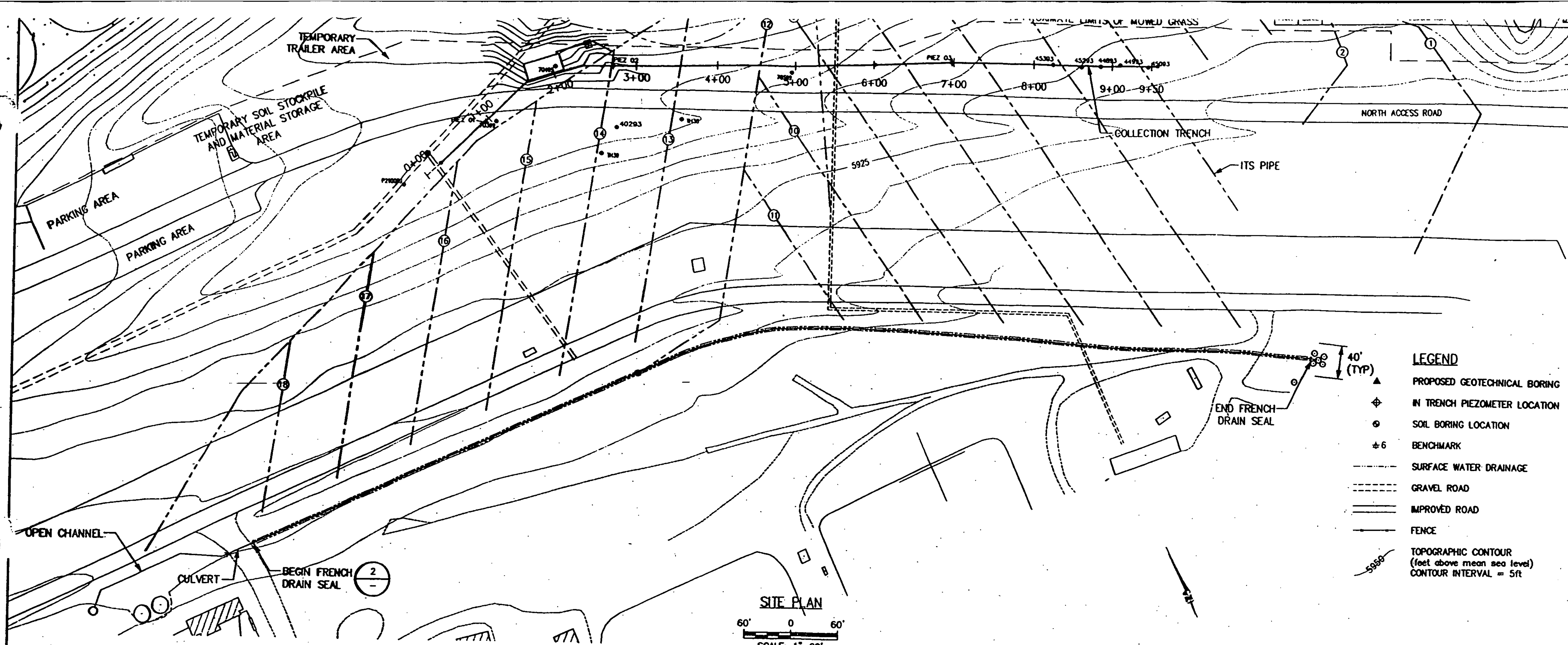
BLDG./FACILITY: Site
ROOM/AREA: N/A
DWG COORD./COL. NO.: N/A
NEXT ASSEMBLY: N/A
SCALE: AS NOTED

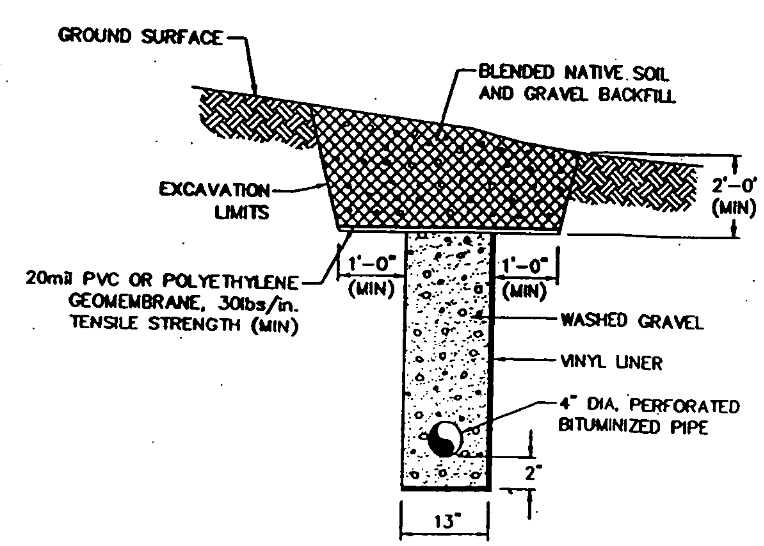
DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN KAF 11/17/99
DRAWN BY: HEALY JH 11/17/99
CHECKED BY: STENSON
APPROVED BY: WILKINSON
CLASSIFIER:
LANDLORD: PRIMROSE

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

"SOLAR PONDS PLUME TREATMENT SYSTEM"
CONVEYANCE PIPE PLAN & PROFILE STA 0+00 TO DISCHARGE AREA

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0105 | A |




2 — TYPICAL FRENCH DRAIN SEAL SECTION
NOT TO SCALE

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| A | AS BUILT |
| ISSUE | DESCRIPTION |

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench

BLDG./FACILITY: Site — ROOM/AREA: N/A — CAD COORD./COL. NO.: N/A — SCALE: AS NOTED — N/A

DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN KAF 10/26/99
DRAWN BY: HEALY JH 10/26/99
CHECKED BY: STENSON
APPROVED BY: WILKINSON
CLASSIFIER
LANDLORD: PRIMROSE

T0099204
PROJECT/WCF NO.

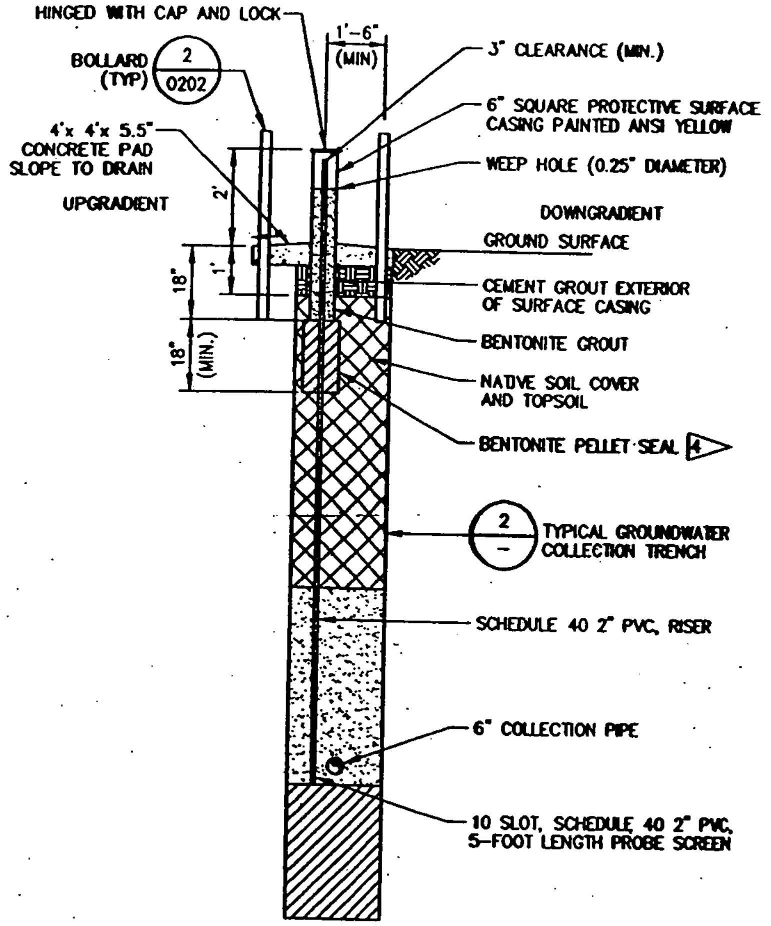
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

SOLAR PONDS PLUME TREATMENT SYSTEM
ITS SEAL PLAN & SECTION

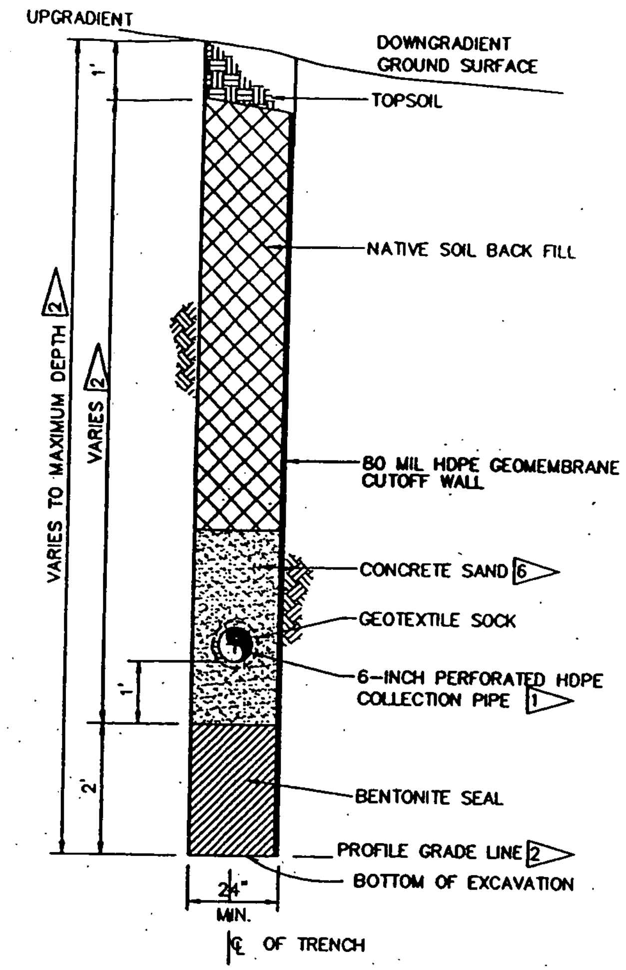
| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0106 | A |

44

PART | QUAN. | DESCRIPTION | MATERIAL




1 / 0102 TYPICAL TRENCH PIEZOMETER SECTION
NOT TO SCALE




2 / 0102 TYPICAL GROUNDWATER COLLECTION TRENCH CROSS SECTION
NOT TO SCALE

NOTES:

1. COLLECTION PIPE PLACED ON A MINIMUM OF 12 INCHES OF CONCRETE SAND.
2. SEE DRAWINGS 51649-0102 THROUGH 51649-0104 FOR PROFILE GRADE ELEVATIONS.
3. TRENCH PIEZOMETER LOCATIONS ARE SHOWN ON DRAWINGS 0102 THROUGH 0104.
4. HYDRATED BENTONITE SEAL BETWEEN PVC RISER PIPE AND SURFACE CASING, AND A MINIMUM 2" THICKNESS AROUND EXTERIOR OF SURFACE CASING AS SHOWN.
5. NOT USED
6. MINIMUM 1 FOOT OF CONCRETE SAND OVER COLLECTION PIPE; TOP OF SAND AS SHOWN.

OHM Energy Services Corporation
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| ISSUE | DESCRIPTION |
|---|---|
| A | AS BUILT |

KEYWORDS: 1. Contamination; 2. Groundwater; 3. Remedial; 4. Treatment; 5. Trench
BLDG./FACILITY: Site
BOOK/AREA: N/A
DWG COORD./COL. NO.: N/A
NEXT ASSEMBLY: N/A
SCALE: AS NOTED

| | | | |
|---|---|---|---|
| DESIGN COMPANY: OHM/Parsons | | | |
| DESIGNED BY | FRIESEN | KAF | 10/26/99 |
| DRAWN BY | HEALY | JH | 10/26/99 |
| CHECKED BY | STENSON | | 1/4/00 |
| APPROVED BY | WILKINSON | | 1/4/00 |
| CLASSIFIER | | | |
| CAROLOND | PRIMROSE | | |

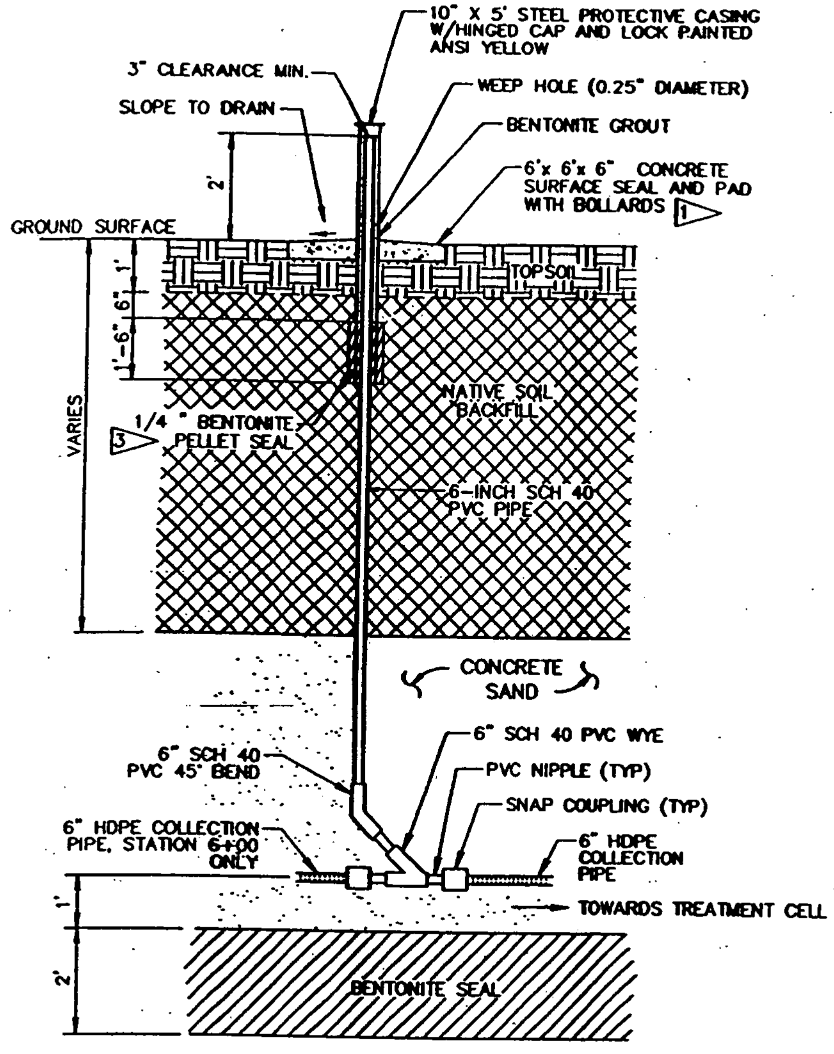
T0099204
PROJECT/WO# NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

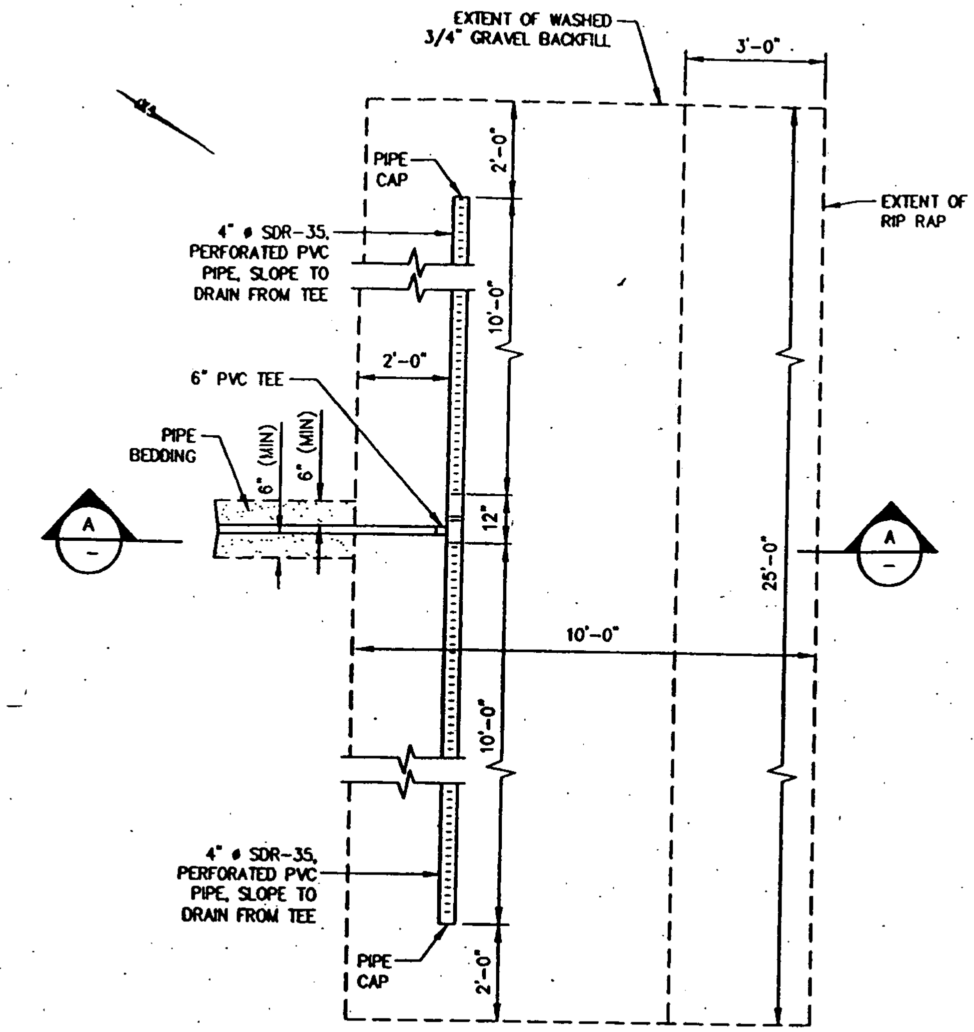
SOLAR PONDS PLUME TREATMENT SYSTEM
TRENCH PIEZOMETER AND COLLECTION TRENCH SECTION

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0107 | A |

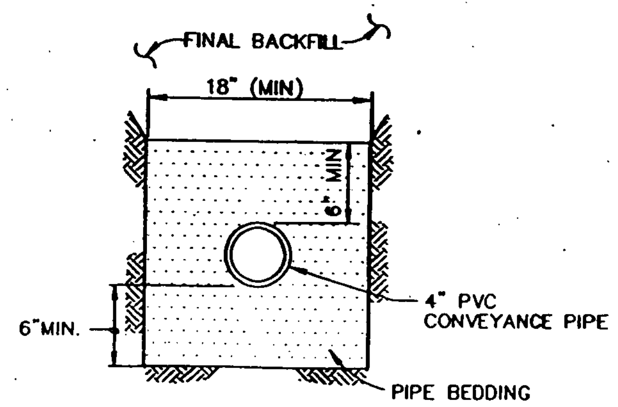
45




1 / 0102 COLLECTION PIPE CLEANOUT
NOT TO SCALE

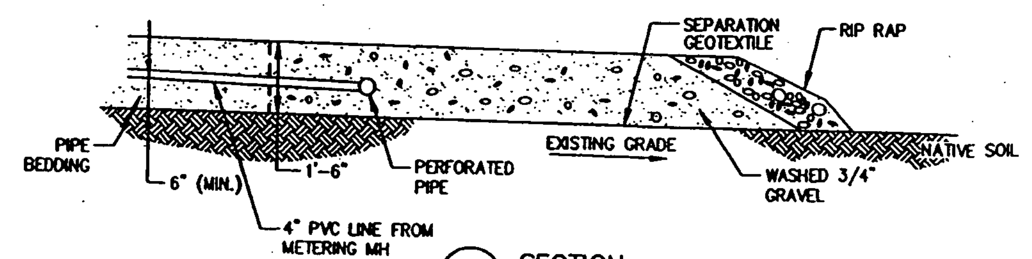



PLAN




SEE SPECS. FOR COMPACTION AND MATERIAL REQUIREMENTS

2 / 0105 CONVEYANCE PIPE BEDDING DETAIL
NOT TO SCALE




A SECTION

3 / 0105 DISCHARGE AREA DETAIL
NOT TO SCALE

NOTES:

1. THREE BOLLARDS MINIMUM 2 FEET FROM CASING, EMBEDDED IN CONCRETE PAD. SEE DETAIL 2 / 0202
2. NOT USED
3. HYDRATED BENTONITE SEAL BETWEEN PVC RISER PIPE AND SURFACE CASING, AND A MINIMUM 2" THICKNESS AROUND EXTERIOR OF CASING AS SHOWN.

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| ISSUE | DESCRIPTION |
|---|---|
| A | AS BUILT |

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench

BLDG./FACILITY: Site
ROOM/AREA: N/A
DWG CODE/JOB NO.: N/A
NEXT ASSEMBLY: N/A
SCALE: AS NOTED

DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN KAF 10/26/99
DRAWN BY: HEALY JH 10/26/99
CHECKED BY: STENSON
APPROVED BY: WILKINSON
CLASSIFIER:
LANDLORD: PRIMROSE

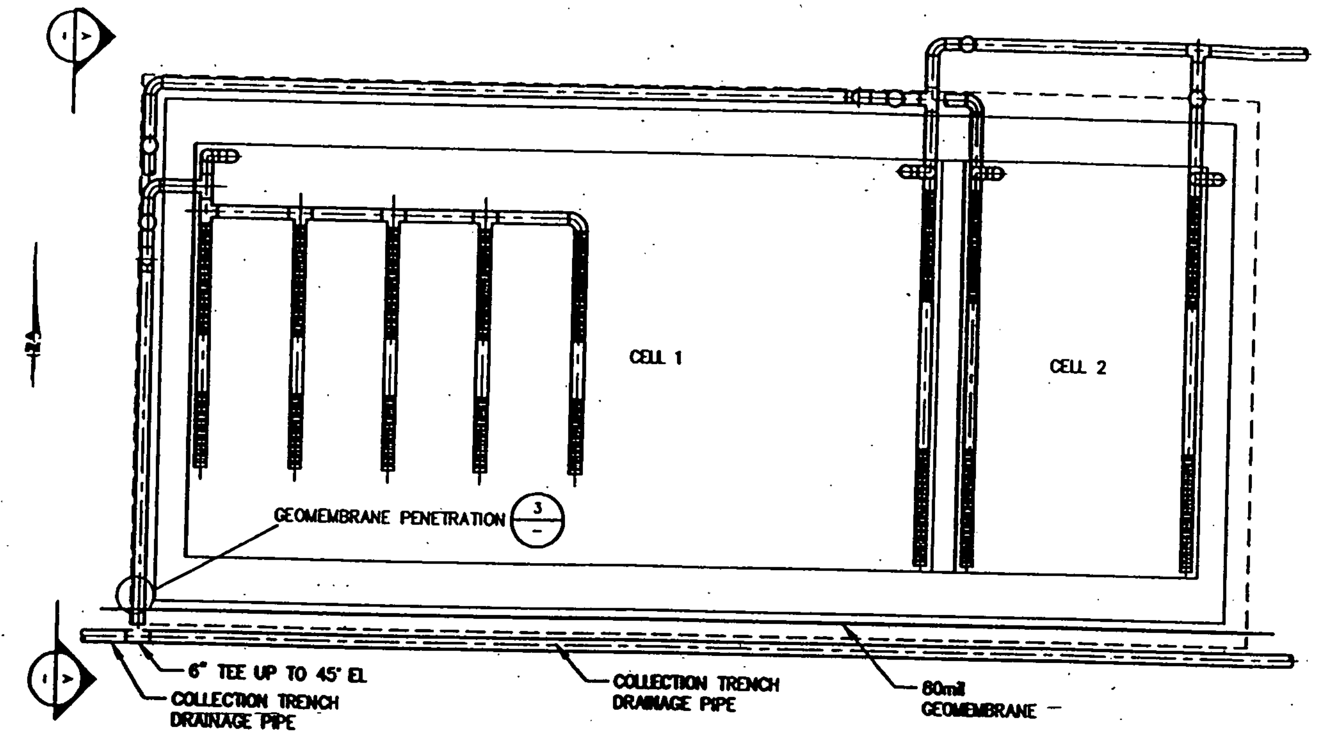
T0099204
PROJECT/WCF NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

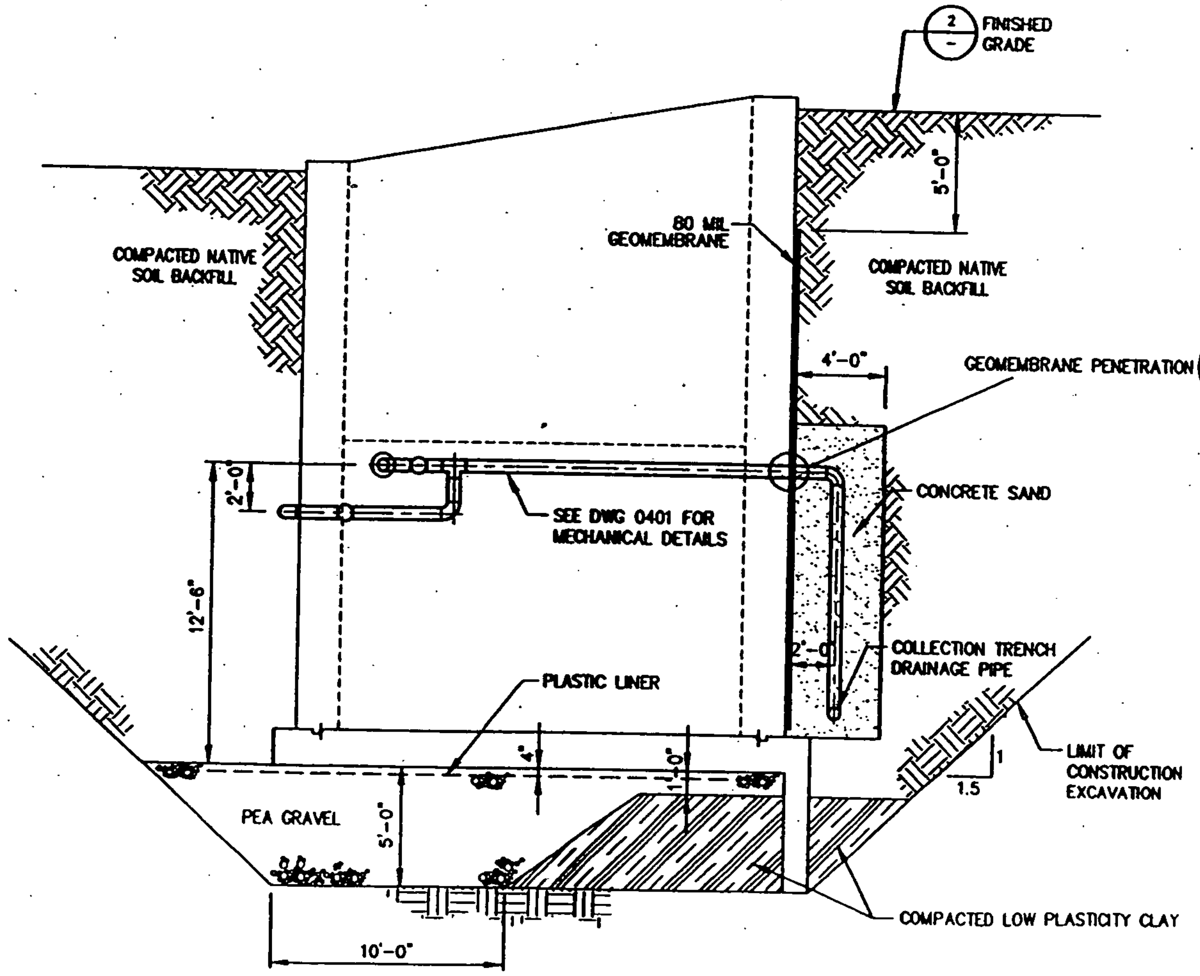
SOLAR PONDS PLUME TREATMENT SYSTEM
TRENCH CLEANOUT, DISCHARGE AREA AND PIPE BEDDING DETAILS

| SIZE | DRAWING NUMBER | ISSUE |
|---|---|---|
| D | 51649-0108 | A |

46

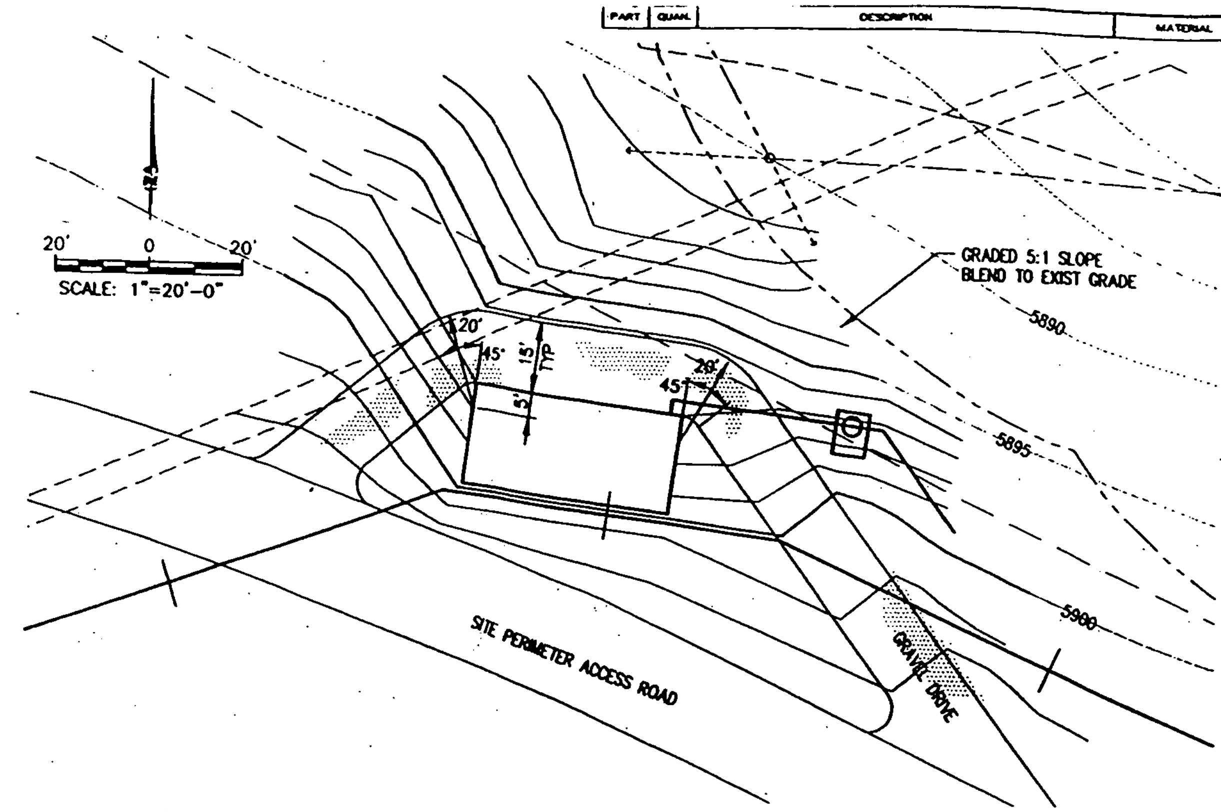



PLAN

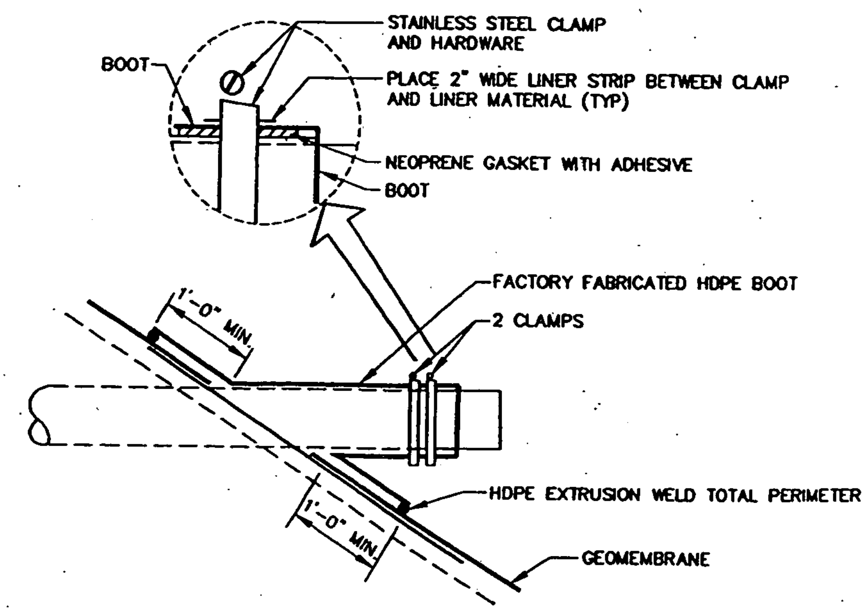



A SECTION

1 0102 TREATMENT SYSTEM DETAIL
SCALE: 1/4" = 1'-0"




2 0105 2 TREATMENT CELL AREA GRADING PLAN




3 TYPICAL GEOMEMBRANE PENETRATION
SCALE: NOT TO SCALE

OHM Energy Services Corporation

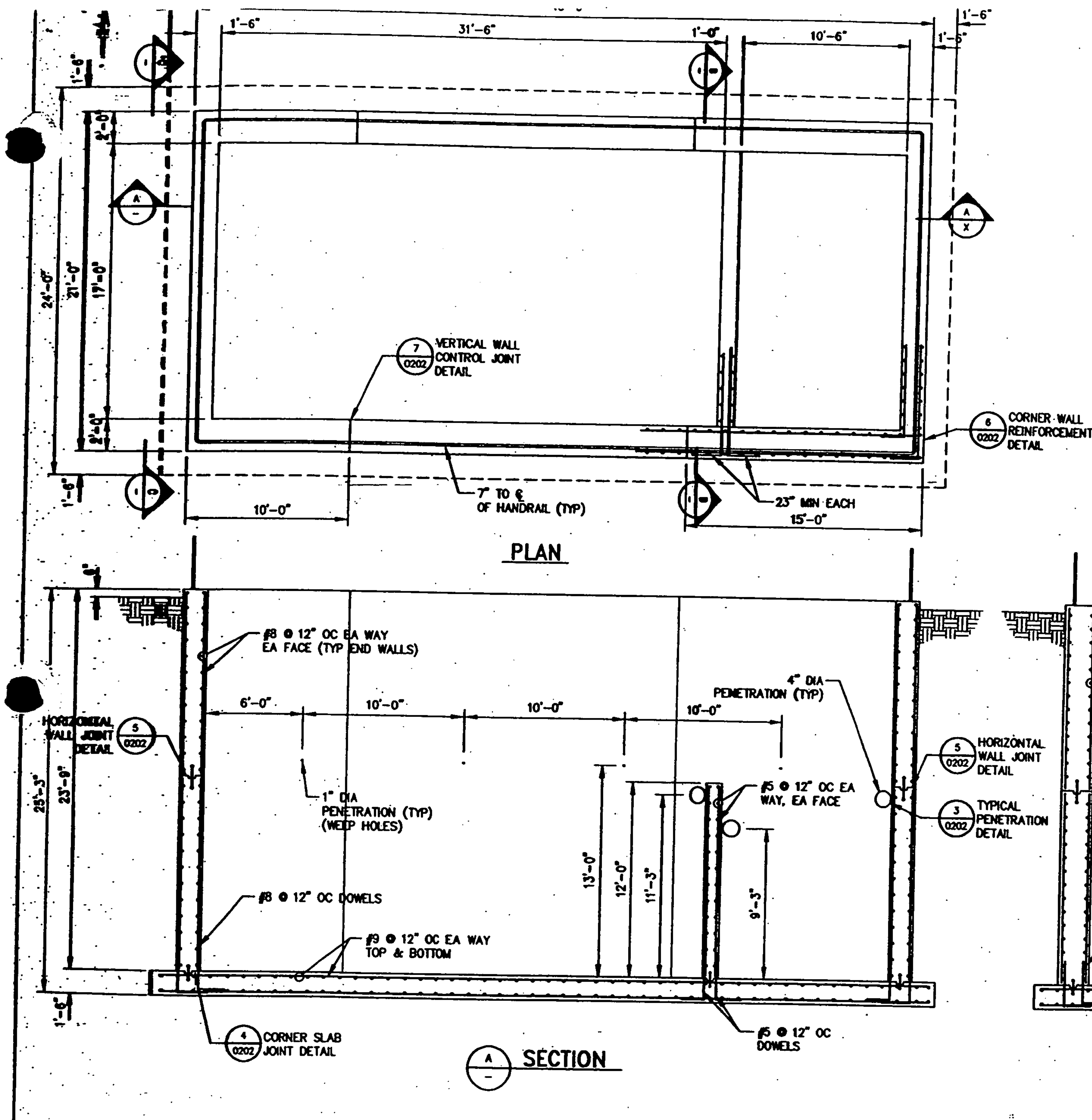
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

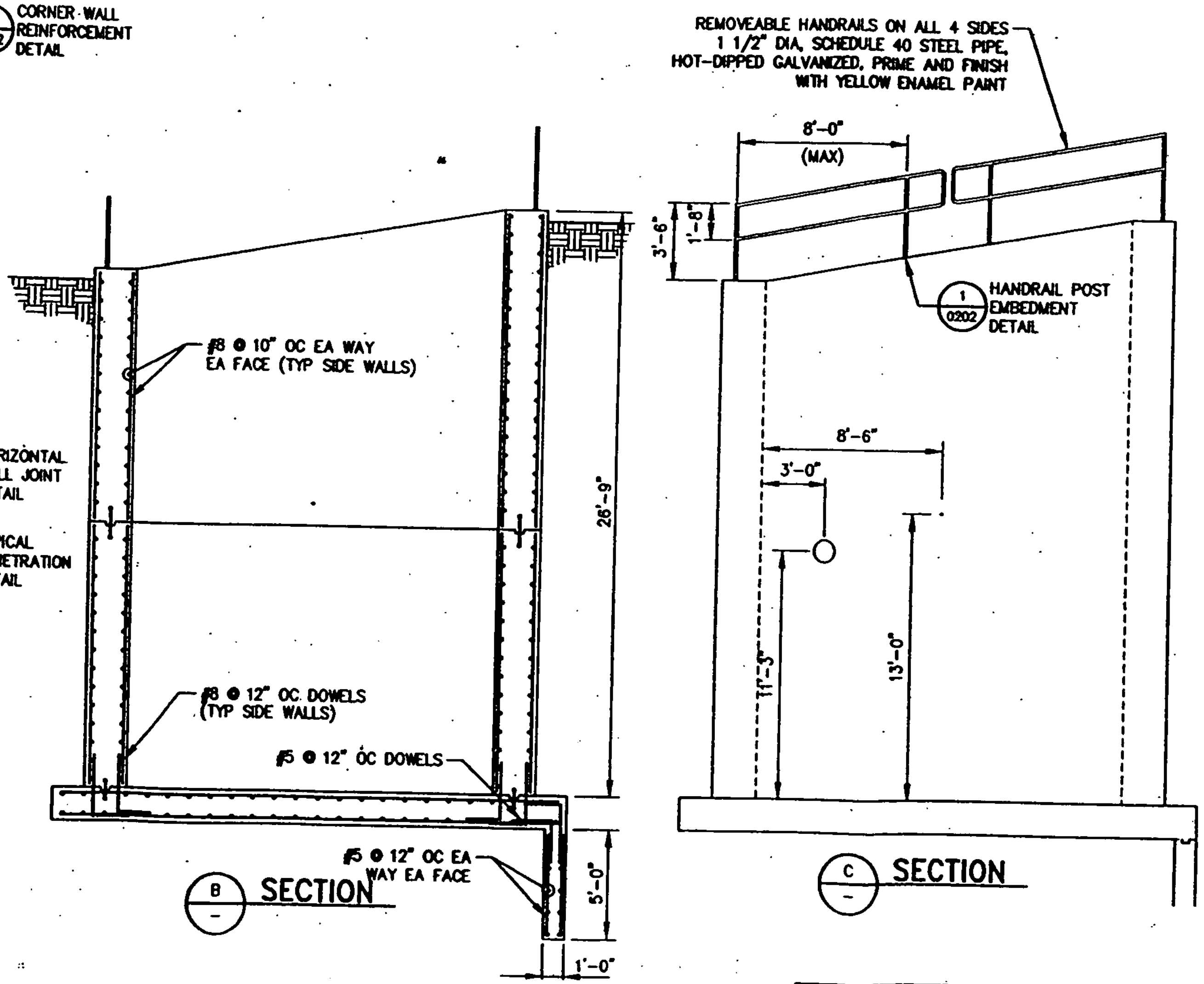
| | | | |
|---|---|---|---|
| ISSUE: A | DESCRIPTION: AS BUILT | | PROJECT/WCF NO.: T0099204 |
| KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons<br>DESIGNED BY: FRIESEN KAF 10/26/99<br>DRAWN BY: HEALY JH 10/26/99<br>CHECKED BY: STENSON<br>APPROVED BY: WILKINSON | U.S. DEPARTMENT OF ENERGY<br>ROCKY FLATS OFFICE GOLDEN, COLORADO<br>Rocky Flats Environmental Technology Site<br>GOLDEN, COLORADO |
| BLDG./FACILITY: Site | REMOVE BURRS AND SHARP EDGES | | SOLAR PONDS PLUME TREATMENT SYSTEM<br>TREATMENT SYSTEM CIVIL DETAILS |
| ROOM/AREA: N/A | NEXT ASSEMBLY: N/A | CLASSIFIER | |
| GRID COORD./COL. NO.: N/A | SCALE: AS NOTED | CARDLORD: PRIMROSE | SIZE: D DRAWING NUMBER: 51649-0109 ISSUE: A |

47

NOTES:

1. CONCRETE MINIMUM STRENGTH: 4000 PSI AT 28 DAYS.
2. REINFORCING STEEL: DEFORMED BARS CONFORMING TO ASTM A 615 GRADE 60. DOWEL BARS: DEFORMED BARS CONFORMING TO ASTM A 615 GRADE 60.
3. ALL CONCRETE AND REINFORCING STEEL SHALL BE FURNISHED, FABRICATED AND ERECTED IN ACCORDANCE WITH THE ACI STANDARD BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE ACI 318-95.
4. ALL REINFORCING STEEL DETAILED IN ACCORDANCE WITH THE MOST RECENT VERSION OF ACI 315 "DETAILS AND DETAILING OF CONCRETE REINFORCEMENT".
5. PRIOR TO PLACING CONCRETE, ALL REINFORCING STEEL, DOWELS, WATERSTOPS, AND SLEEVES FOR PENETRATIONS, WERE WELL SECURED IN POSITION AND APPROVED BY THE CONTRACTOR.
6. LOCATION OF ALL CONSTRUCTION JOINTS OR OTHER TYPES OF JOINTS OTHER THAN THOSE SPECIFIED, AND DETAILS OF ALL SLEEVES, OPENINGS, OR OTHER ATTACHMENTS NOT SHOWN ON THE DRAWINGS AS APPROVED BY THE CONTRACTOR PRIOR TO CONSTRUCTION.
7. VERTICAL CONTROL JOINTS IN LONG WALLS, PLACED WHERE INDICATED OR WHERE APPROVED BY CONTRACTOR, BUT NOT MORE THAN 25' APART AND WITHIN 10' TO 15' OF CORNERS. NOT PLACED IN LOCATIONS WHERE DEVELOPEMENT LENGTH OF DOWELS WILL BE LESS THAN REQUIRED.
8. EXPOSED EDGES OF CONCRETE 3/4" CHAMFER.
9. REINFORCING STEEL FURNISHED AND INSTALLED ARE FREE OF EXCESSIVE RUST, GREASE, MILL SCALE, OR ANY MATERIAL WHICH MAY AFFECT ITS BOND WITH CONCRETE.
10. SPLICES USED ONLY WHERE REQUIRED BASED ON AVAILABLE REINFORCEMENT LENGTHS. WHERE REQUIRED, SPLICES ARE CLASS B SPLICE CONFORMING TO ACI 318-95. LAP #9 BARS 61" MINIMUM, LAP #8 BARS 49" MINIMUM AND LAP #5 BARS 16" MINIMUM, ENCLOSE WITH STIRRUPS OR TIES. TRANSVERSE SPACING OF #8 BARS AND #9 BARS NO GREATER THAN 6" AND SPACING OF #5 BARS NO GREATER THAN 3". SPLICES STAGGERED A MINIMUM OF 24" LONGITUDINALLY.
11. MINIMUM CONCRETE COVER OVER REINFORCING STEEL AS FOLLOWS, UNLESS OTHERWISE NOTED:
    A. BOTTOM OF SLAB, 3"
    B. ELSEWHERE, 2"
12. DESIGN LOADS:
    EXTERIOR SURCHARGE 300psf
    INTERIOR SURCHARGE 75psf
    NATIVE SOIL 116psf
    CONCRETE SAND 130psf
    ALLOWABLE BEARING PRESSURE 4000psf




4' 0 4'
SCALE: 1/4"=1'-0"

## 1 0105 TREATMENT SYSTEM STRUCTURAL PLAN

SCALE: 1/4" = 1'-0"

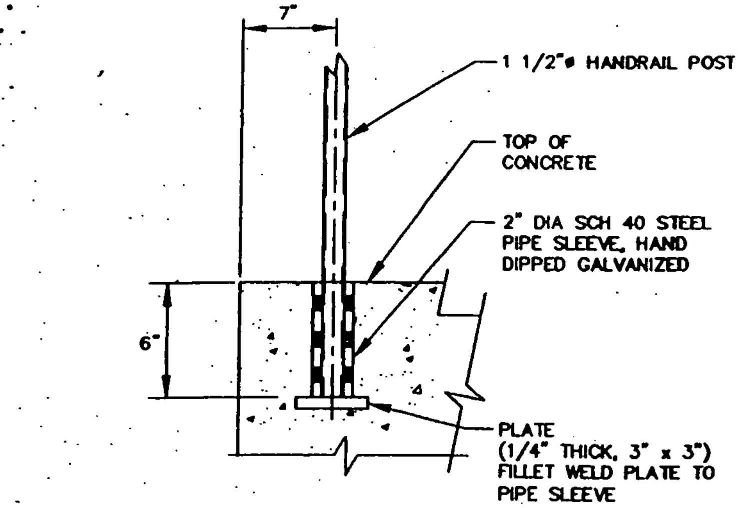
| | | | |
|---|---|---|---|
| A ISSUE | AS BUILT DESCRIPTION | | PROJECT/WCF NO. |
| KEYWORDS | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO |
| 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench | | DESIGNED BY FRIESEN KAF 11/26/99 | Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| | | DRAWN BY HEALY JH 11/26/99 | |
| | | CHECKED BY STENSON 2/16/00 | SOLAR PONDS PLUME TREATMENT SYSTEM |
| BLDG/FACILITY Site | REMOVE BURRS AND SHARP EDGES | APPROVED BY WILKINSON 2/16/2000 | TREATMENT SYSTEM STRUCTURAL PLAN |
| ROOM/AREA N/A | NEXT ASSEMBLY N/A | CLASSIFIER | SIZE D |
| DWG GENERAL SERIES N/A | SCALE: AS NOTED | PRIMROSE 2/15/00 | DRAWING NUMBER 51649-0201 ISSUE A |

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

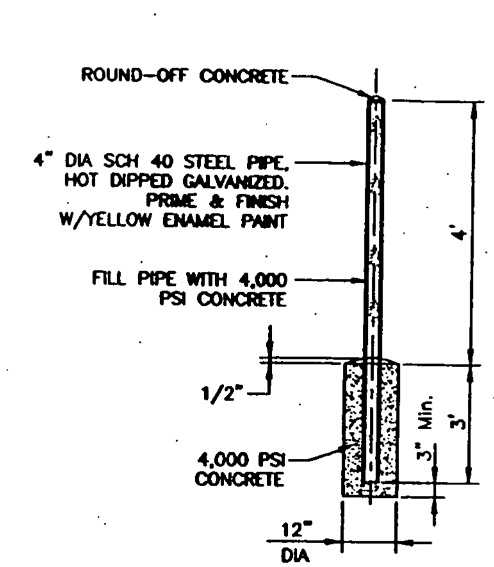
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

AUTOCAD COMPUTER GENERATED P\ACD\51649\0201\A

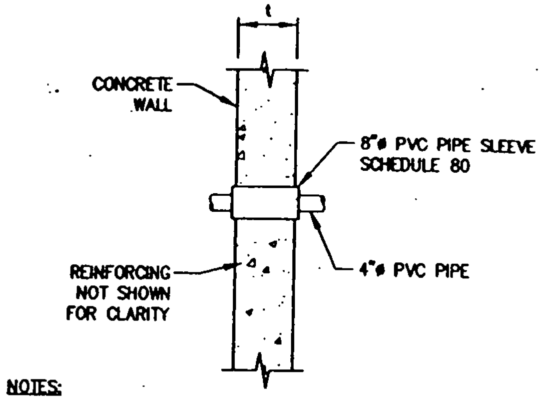
48




1 (0201) **HANDRAIL POST EMBEDMENT DETAIL**
NOT TO SCALE



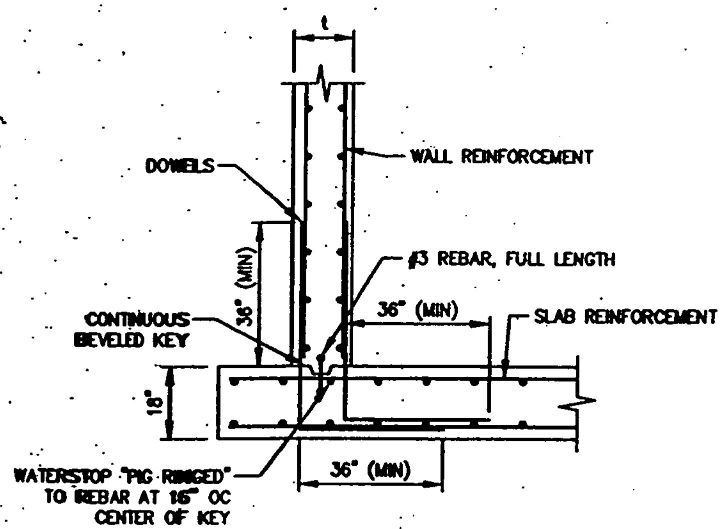

2 (0107) 2 (0108) 2 (0401) **PERMANENT BOLLARD DETAIL**
NOT TO SCALE




NOTES:

1. PENETRATION LOCATED IN WALL AS SHOWN. FRAMED WITH REBAR.
2. SLEEVE EXTENDS 1" MIN BEYOND BOTH SIDES OF WALL. CENTER SLEEVE AROUND PIPE. LINK SEAL PROVIDED FOR WATER RESISTANT JOINT SEALANT BETWEEN SLEEVE AND PIPE.

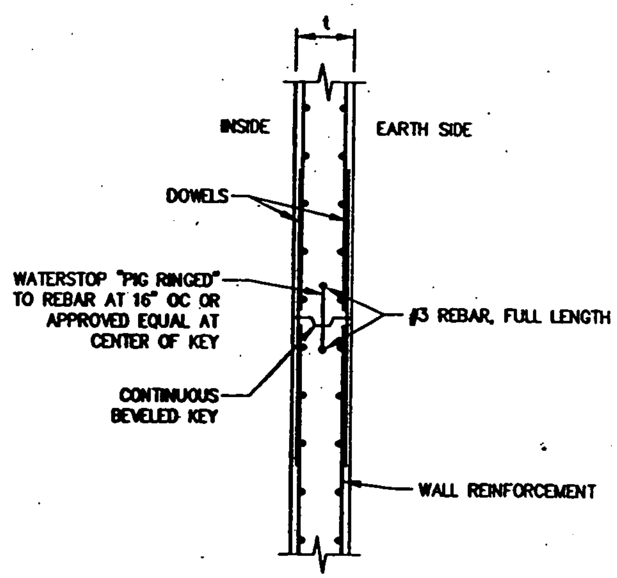
3 (0201) **TYPICAL PENETRATION DETAIL**
NOT TO SCALE




NOTES:

1. KEY CENTERED ON WALL.
2. KEY 2" DEEP BY t/3 WIDE.
3. WATERSTOP AND JOINT SEALANT PROVIDED FOR FULL LENGTH OF WALL ALONG ALL FOUR SIDES.
4. REINFORCING BARS DISCONTINUED AND DOWELS PROVIDED TO MATCH SIZE AND SPACING OF VERTICAL REINFORCEMENT ABOVE JOINT.

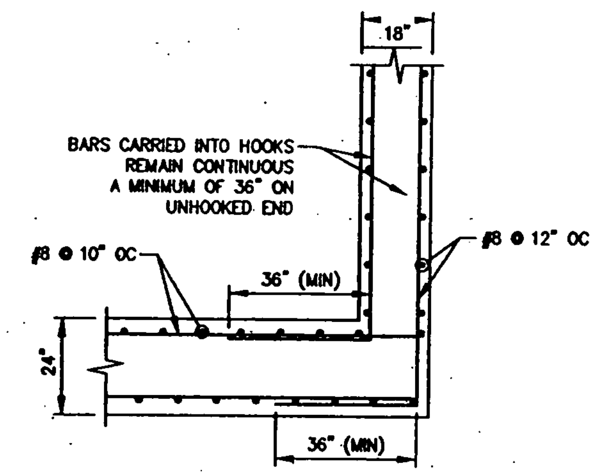
4 (0201) **CORNER SLAB DETAIL**
SCALE: 1/2" = 1'-0"



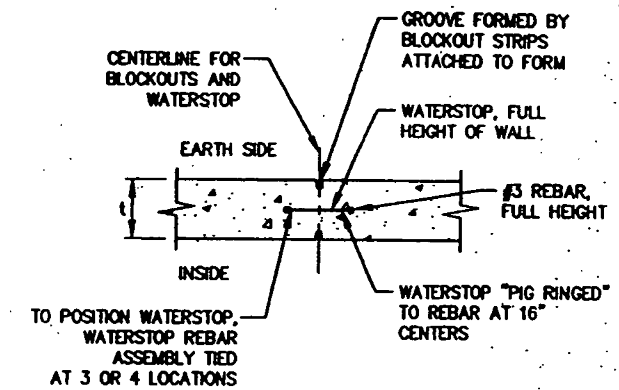

NOTES:

1. KEY CENTERED ON WALL.
2. KEY 2" DEEP BY t/3 WIDE.
3. WATERSTOP AND JOINT SEALANT PROVIDED FOR FULL LENGTH OF WALL ALONG ALL FOUR SIDES.
4. REINFORCING BARS DISCONTINUED AND DOWELS PROVIDED TO MATCH SIZE AND SPACING OF VERTICAL REINFORCEMENT IN WALL. DOWELS EXTEND 48" ON EACH SIDE OF JOINT, A TOTAL OF 8'-0".

5 (0201) **HORIZONTAL WALL JOINT DETAIL**
SCALE: 1/2" = 1'-0"




6 (0201) **CORNER WALL REINFORCEMENT DETAIL**
SCALE: 1/2" = 1'-0"




NOTES:

1. FORMED GROOVES PROVIDED IN BOTH SIDE FACES OF THE WALL. A TOOLED GROOVE PROVIDED ON THE TOP FACE OF THE WALL.
2. MINIMUM SIDE FACE DEPTH 1/8 OF WALL THICKNESS ON EACH FACE OR 1" MINIMUM. MINIMUM TOP FACE DEPTH OF 1".
3. WATERSTOP AND JOINT SEALANT PROVIDED FOR FULL LENGTH ON INSIDE FACE OF WALL, ACROSS TOP AND TO 6" BELOW GRADE ON EARTH SIDE OF WALL.
4. REINFORCING BARS STOPPED AND DOWELS PROVIDED TO MATCH SIZE AND SPACING OF HORIZONTAL REINFORCEMENT, DOWELS EXTENDING A MINIMUM OF 63" ON EACH SIDE OF THE JOINT.

7 (0201) **VERTICAL WALL CONTROL JOINT DETAIL**
SCALE: 1/2" = 1'-0"

4' 0 4'
SCALE: 1/4"=1'-0"

OHM Energy Services Corporation
PARSONS
Denver, Colorado (303) 831-8100

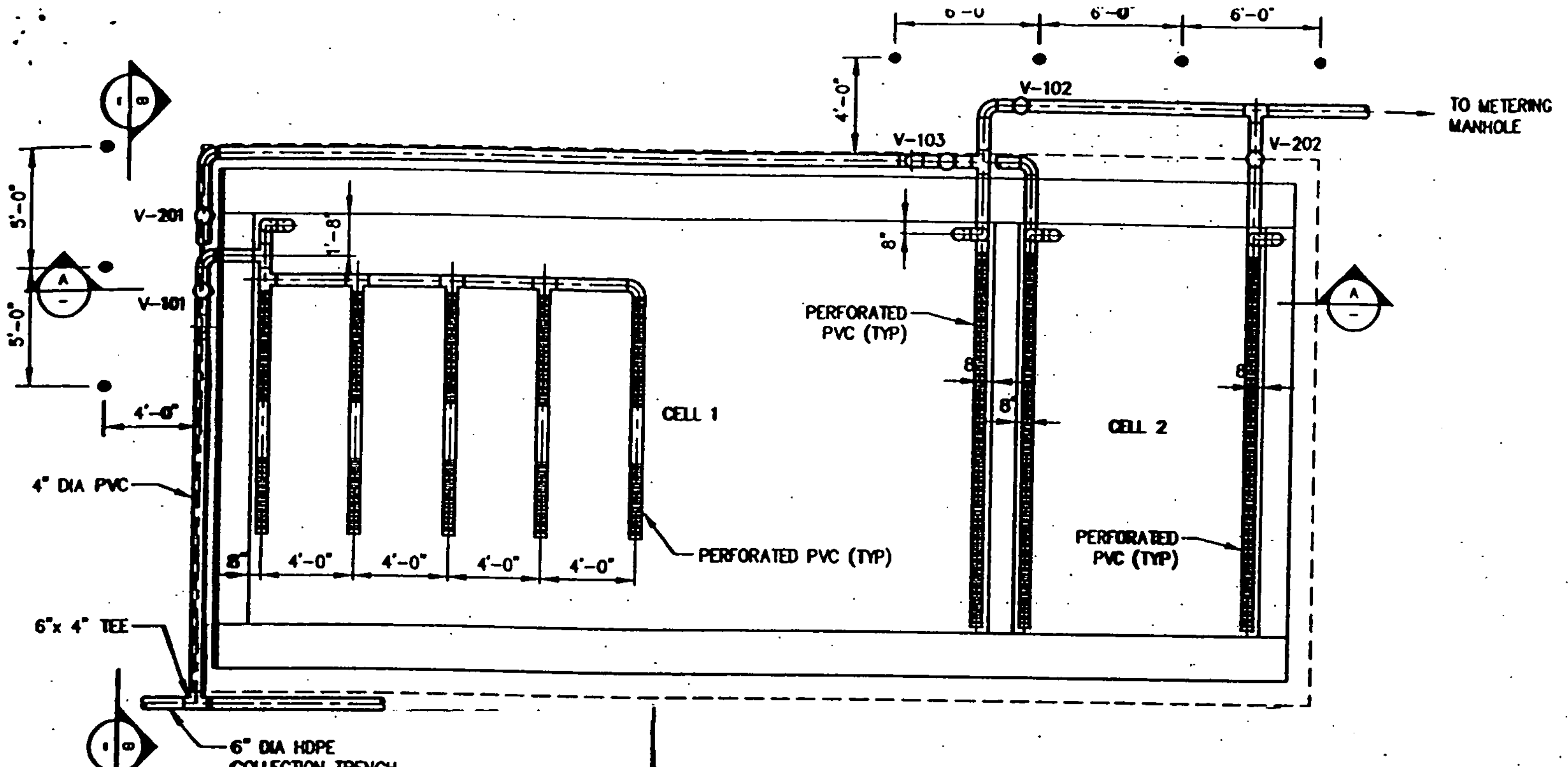
A AS BUILT (ISSUE / DESCRIPTION)

KEYWORDS: 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench
BLDG./FACILITY: Site
N/A
N/A

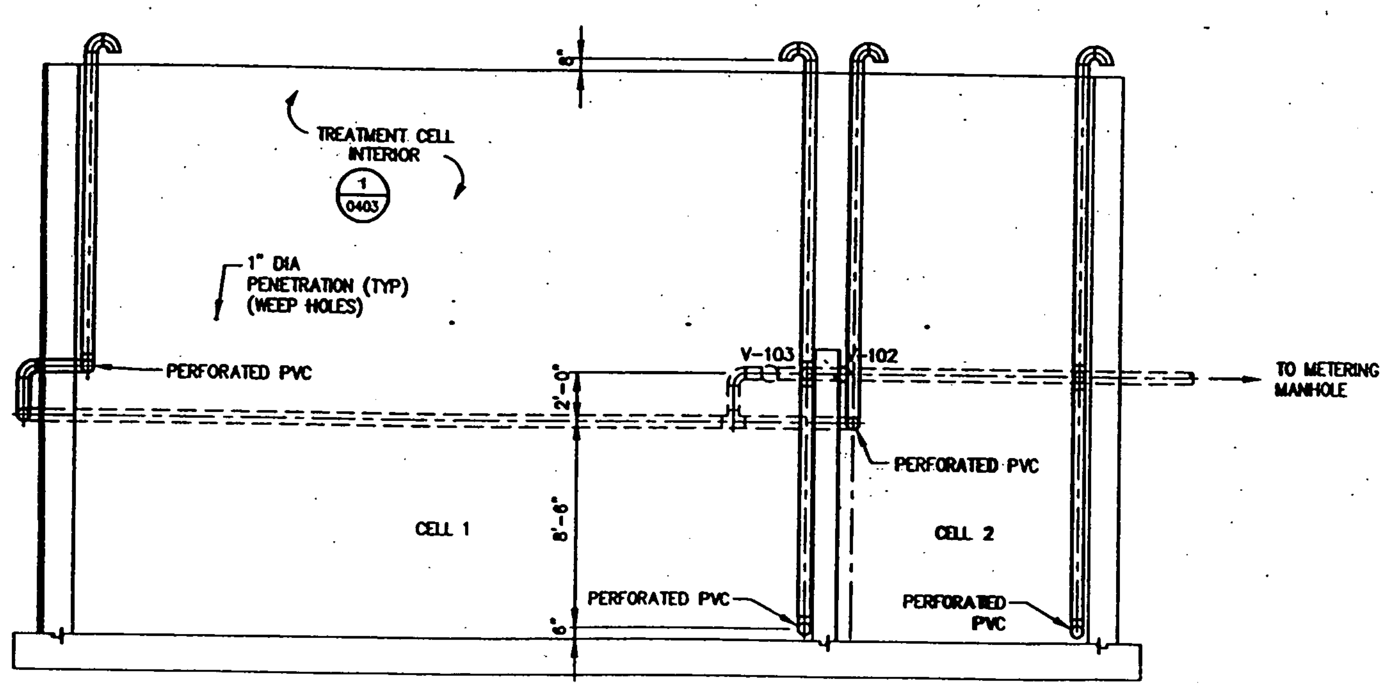
DESIGN COMPANY: OHM/Parsons
DESIGNED BY: FRIESEN KAF 10/26/99
DRAWN BY: HEALY JH 10/26/99
CHECKED BY: STENSON
APPROVED BY: WILKINSON
N/A
SCALE: AS NOTED
PRIMROSE

PROJECT/WCF NO.
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
SOLAR PONDS PLUME TREATMENT SYSTEM
TREATMENT SYSTEM STRUCTURAL DETAILS
SIZE: D DRAWING NUMBER: 51649-0202 ISSUE: A

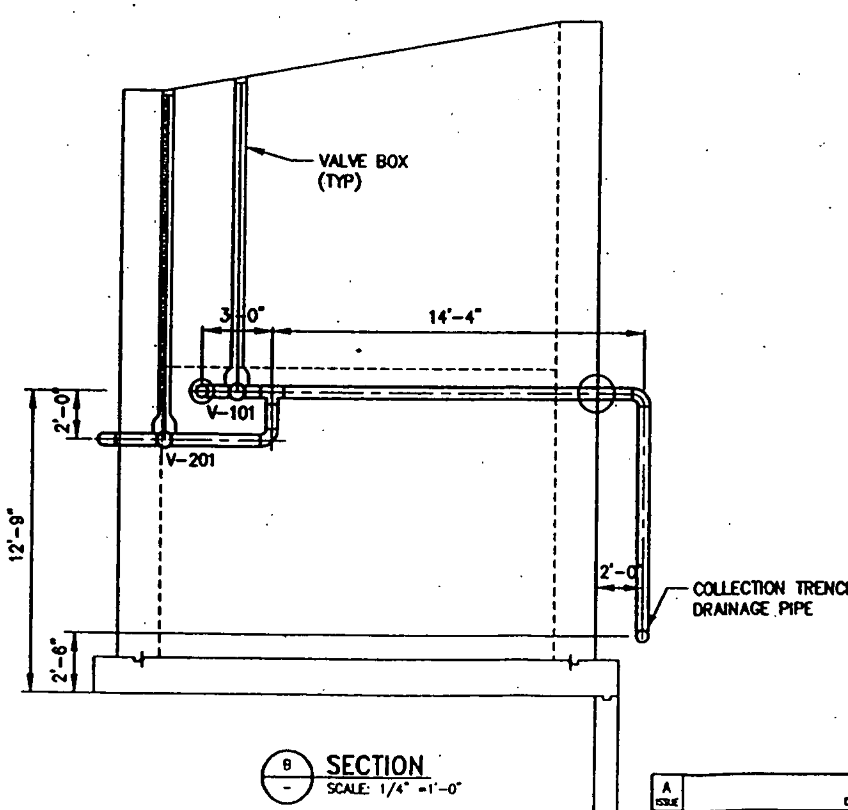
AUTOCAD COMPUTER GENERATED R\ACD\51649\0202\A




**PLAN**
SCALE: 1/4" =1'-0"




A SECTION
SCALE: 1/4" =1'-0"




B SECTION
SCALE: 1/4" =1'-0"

4' 0 4'
SCALE: 1/4"=1'-0"

## 1/0102 TREATMENT SYSTEM MECHANICAL DETAIL
SCALE: 1/4" = 1'-0"

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|

**TREATMENT CELL OPERATING MODES**

| Operating Modes | INITIAL VALVES | | | | |
|---|---|---|---|---|---|
| | Cell 1 Inlet V-101 | Cell 1 Outlet V-102 | Transfer Valve V-103 | Cell 2 Inlet V-201 | Cell 2 Outlet V-202 |
| Cell 1 Only | OPEN | OPEN | CLOSED | CLOSED | CLOSED |
| Cell 2 Only | CLOSED | CLOSED | CLOSED | OPEN | OPEN |
| Cell 1 & 2 in Series | OPEN | CLOSED | OPEN | CLOSED | OPEN |
| Cell 1 & 2 in Parallel | OPEN | OPEN | CLOSED | OPEN | OPEN |

**LEGEND**

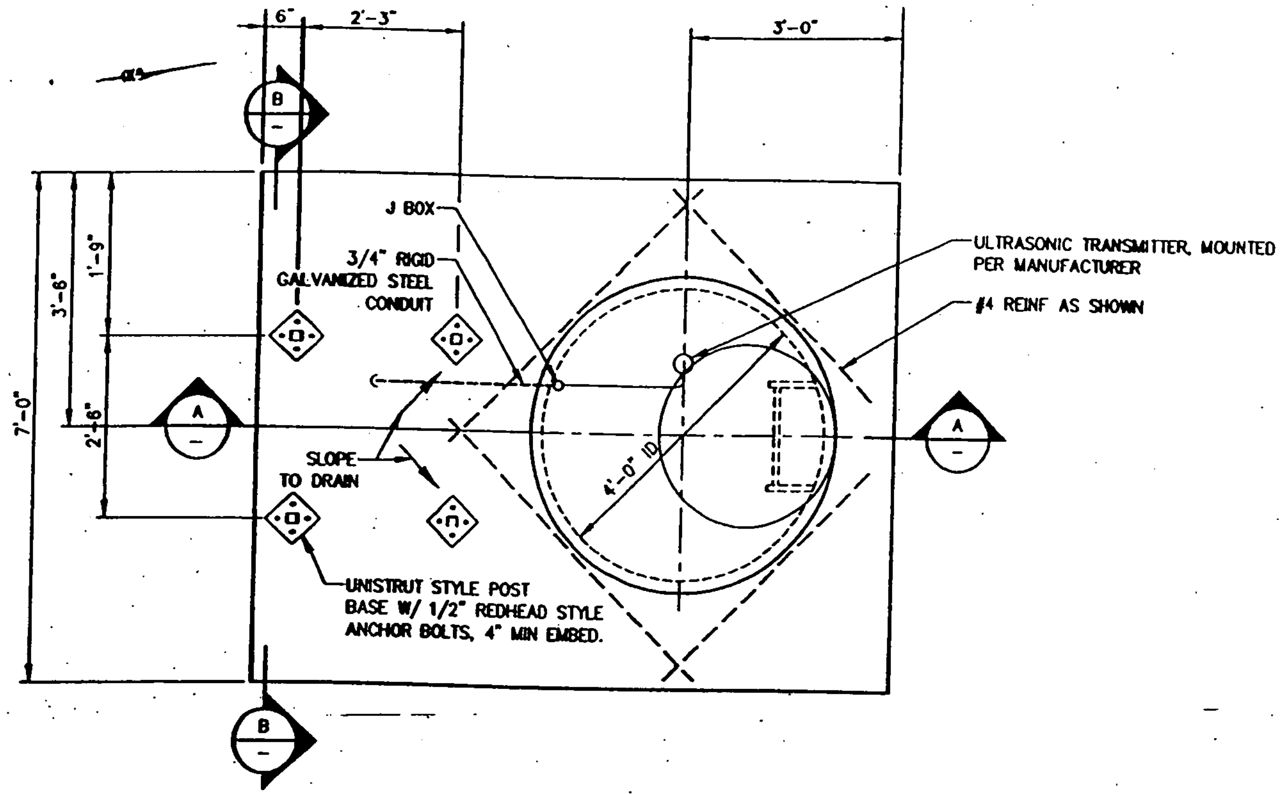
V-103 ○ BALL VALVE
● BOLLARDS 2/0202

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

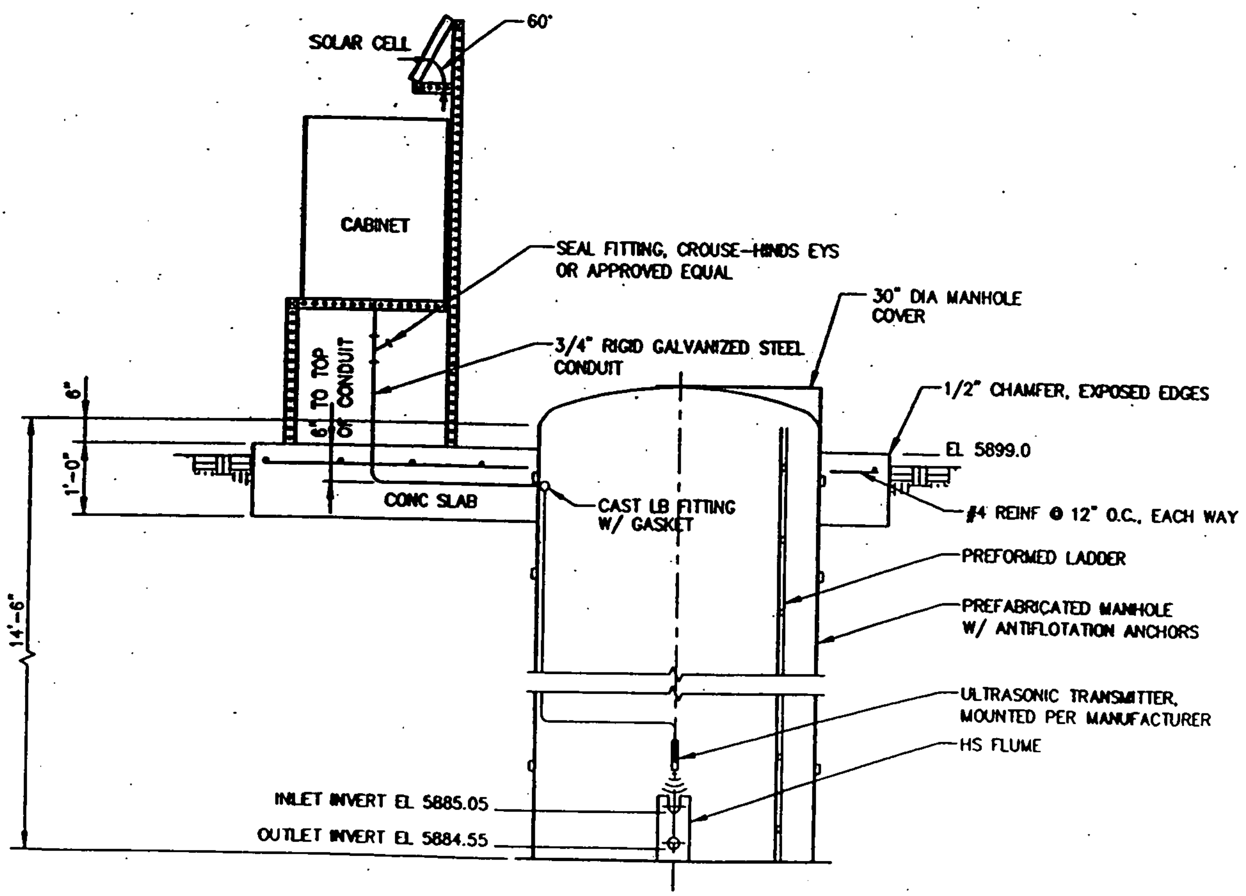
PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1.Contamination 2.Groundwater 3.Remedial 4.Treatment 5.Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| GRID COORD./COL. NO. | N/A |
| TOLERANCES | FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE |
| REMOVE BURRS AND SHARP EDGES | |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 10/26/99 |
| DRAWN BY | HEALY JH 10/26/99 |
| CHECKED BY | STENSON 1/4/2000 |
| APPROVED BY | WILKINSON 1/4/2000 |
| CLASSIFIER | |
| LANDLORD | PRIMROSE |
| PROJECT/WCF NO. | T0099204 |
| | U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO |
| | Rocky Flats Environmental Technology Site GOLDEN, COLORADO |
| | SOLAR PONDS PLUME TREATMENT SYSTEM |
| | TREATMENT SYSTEM MECHANICAL PLAN |
| SIZE | D |
| DRAWING NUMBER | 51649-0401 |
| ISSUE | A |

50

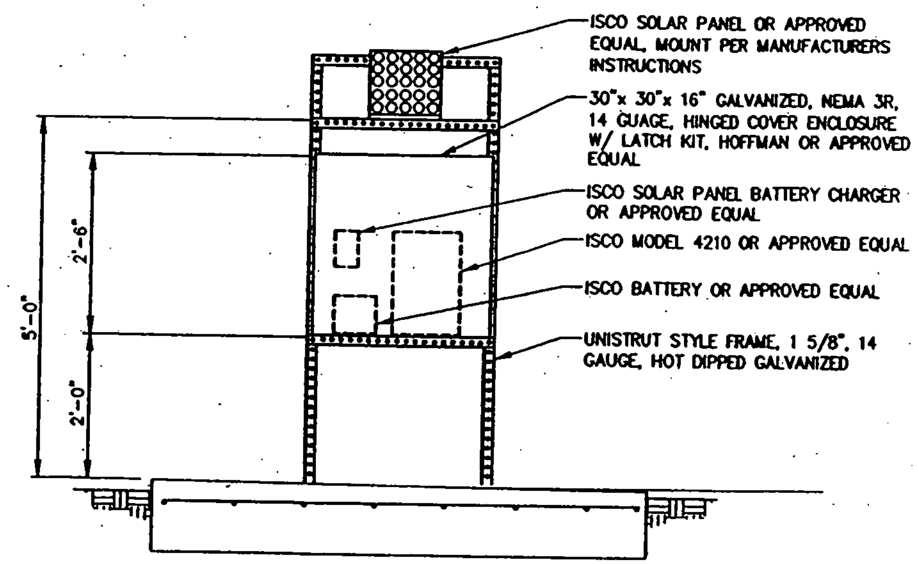



PLAN – TANK COVER




A SECTION

1 / 0105 METER MH DETAIL
NO SCALE




B SECTION

1' 0 1'
SCALE: 3/4"=1'-0"

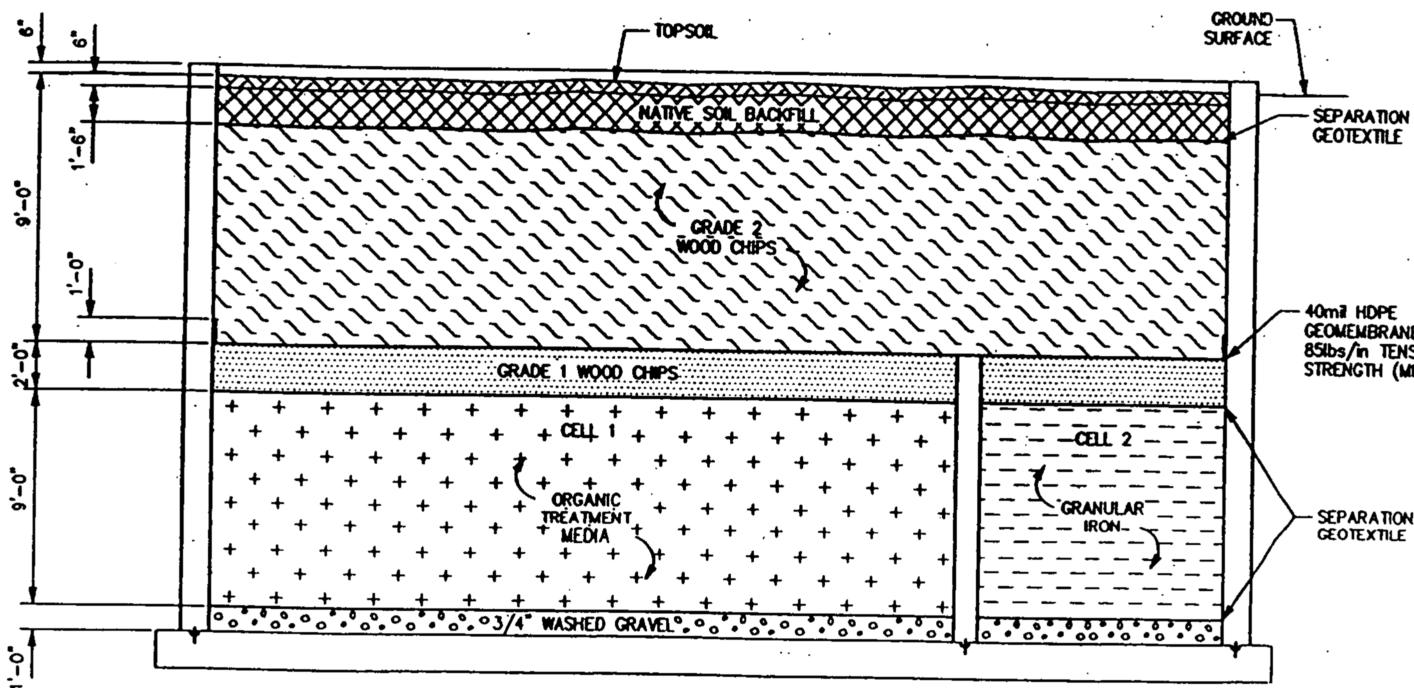
OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | | | | | |
|---|---|---|---|---|---|
| A (ISSUE) | AS BUILT (DESCRIPTION) | | | | T0099204 (PROJECT/WCF NO.) |
| KEYWORDS | TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE | DESIGN COMPANY: OHM/Parsons | | | U.S. DEPARTMENT OF ENERGY, ROCKY FLATS OFFICE, GOLDEN, COLORADO |
| 1.Contamination | | DESIGNED BY: FRIESEN | KAF | 10/26/99 | Rocky Flats Environmental Technology Site, GOLDEN, COLORADO |
| 2.Groundwater | | DRAWN BY: HEALY | JH | 10/26/99 | |
| 3.Remedial | | CHECKED BY: STENSON | | 1/11/2000 | SOLAR PONDS PLUME TREATMENT SYSTEM |
| 4.Treatment | | APPROVED BY: WILKINSON | | 1/11/2000 | METERING MANHOLE PLAN, SECTIONS & DETAILS |
| 5.Trench | REMOVE BURRS AND SHARP EDGES | | | | |
| BLDG./FACILITY: Site | NEXT ASSEMBLY | | | | |
| ROOM/AREA: N/A | N/A | CLASSIFIER | | | SIZE: D — DRAWING NUMBER: 51649-0402 — ISSUE: A |
| SMB CODING/COL NO.: N/A | SCALE: AS NOTED | LANDLORD: PRIMROSE | | | |

51

| PART | QUAN. | DESCRIPTION | MATERIAL |
|---|---|---|---|




1 / 0401 DETAIL
SCALE: 1/4" = 1'-0"

4' 0 4'
SCALE: 1/4"=1'-0"

OHM Energy Services Corporation
A Subsidiary of OHM Corporation

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado (303) 831-8100

| | |
|---|---|
| ISSUE | A |
| DESCRIPTION | AS BUILT |
| KEYWORDS | 1.Contamination; 2.Groundwater; 3.Remedial; 4.Treatment; 5.Trench |
| BLDG./FACILITY | Site |
| ROOM/AREA | N/A |
| DWG CODE/JOB NO. | N/A |
| TOLERANCES | FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE |
| NEXT ASSEMBLY | N/A |
| SCALE | AS NOTED |
| DESIGN COMPANY | OHM/Parsons |
| DESIGNED BY | FRIESEN KAF 10/26/99 |
| DRAWN BY | HEALY JH 10/26/99 |
| CHECKED BY | STENSON 1/4/2000 |
| APPROVED BY | WILKINSON 1/4/2000 |
| PROJECT/WCF NO. | T0099204 |
| | U.S. DEPARTMENT OF ENERGY, ROCKY FLATS OFFICE, GOLDEN, COLORADO |
| | Rocky Flats Environmental Technology Site, GOLDEN, COLORADO |
| | SOLAR PONDS PLUME TREATMENT SYSTEM |
| | MECHANICAL DETAILS |
| SIZE | D |
| DRAWING NUMBER | 51649-0403 |
| ISSUE | A |

52

# Appendix B – Solar Ponds Plume Treatment System Manufacturer Operation and Maintenance Information



The literature on the pump (B.1-B.8) was taken from the Dankoff Solar Products website which is the manufacturer of the solar pump controller and solar pump installed at the Solar Ponds Plume Treatment System. The pump model in current use is HR14. The address of the website is as follows:

**http://www.dankoffsolar.com**

The batteries are Concorde Sun Xtender® Batteries Model PVX-2120L. The literature on the batteries (B.9) was from the Concorde Battery website:

**http://www.concordebattery.com**

The charge controller is Morningstar Prostar 30. The literature on the charge controller is from the Morningstar website:

**http://www.morningstarcorp.com/products/ProStar/index.shtml**

53

## B.1 An Introduction to Charge Controllers

By Windy Dankoff

A charge controller is an essential part of nearly all power systems that charge batteries, whether the power source is PV, wind, hydro, fuel, or utility grid. Its purpose is to keep your batteries properly fed and safe for the long term.

The basic functions of a controller are quite simple. Charge controllers block reverse current and prevent battery overcharge. Some controllers also prevent battery over discharge, protect from electrical overload, and/or display battery status and the flow of power. Let's examine each function individually.

Blocking Reverse Current

Photovoltaic panels work by pumping current through your battery in one direction. At night, the panels may pass a bit of current in the reverse direction, causing a slight discharge from the battery. (Our term "battery" represents either a single battery or bank of batteries.) The potential loss is minor, but it is easy to prevent. Some types of wind and hydro generators also draw reverse current when they stop (most do not except under fault conditions).

In most controllers, charge current passes through a semiconductor (a transistor) that acts like a valve to control the current. It is called a "semiconductor" because it passes current only in one direction. It prevents reverse current without any extra effort or cost.

In some controllers, an electromagnetic coil opens and closes a mechanical switch. This is called a relay. (You can hear it click on and off.) The relay switches off at night, to block reverse current.

If you are using a PV array only to trickle-charge a battery (a very small array relative to the size of the battery), then you may not need a charge controller. This is a rare application. An example is a tiny maintenance module that prevents battery discharge in a parked vehicle but will not support significant loads. You can install a simple diode in that case, to block reverse current. A diode used for this purpose is called a "blocking diode."

Preventing Overcharge

When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. (It looks like it's boiling so we sometimes call it that, although it's not actually hot.) There is excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also stress your loads (lights, appliances, etc.) or cause your inverter to shut off.

Preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage. When the voltage drops due to lower sun intensity or an increase in electrical usage, the controller again allows the maximum possible charge. This is called "voltage regulating." It is the most essential function of all charge controllers. The controller "looks at" the voltage, and regulates the battery charging in response.

Some controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called "on/off control." Others reduce the current gradually. This is called "pulse width modulation" (PWM). Both methods work well when set properly for your type of battery.

A PWM controller holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then, it will drop the voltage lower, to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress.

54

The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated patterns of usage, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not.

Control Set Points vs. Temperature

The ideal set points for charge control vary with a battery's temperature. Some controllers have a feature called "temperature compensation." When the controller senses a low battery temperature, it will raise the set points. Otherwise, when the battery is cold, it will reduce the charge too soon. If your batteries are exposed to temperature swings greater than about 30° F (17° C), compensation is essential.

Some controllers have a temperature sensor built in. Such a controller must be mounted in a place where the temperature is close to that of the batteries. Better controllers have a remote temperature probe, on a small cable. The probe should be attached directly to a battery in order to report its temperature to the controller.

An alternative to automatic temperature compensation is to manually adjust the set points (if possible) according to the seasons. It may be sufficient to do this only twice a year, in spring and fall.

Control Set Points vs. Battery Type

The ideal set points for charge controlling depend on the design of the battery. The vast majority of RE systems use deep-cycle lead-acid batteries of either the flooded type or the sealed type. Flooded batteries are filled with liquid. These are the standard, economical deep cycle batteries.

Sealed batteries use saturated pads between the plates. They are also called "valve-regulated" or "absorbed glass mat," or simply "maintenance-free." They need to be regulated to a slightly lower voltage than flooded batteries or they will dry out and be ruined. Some controllers have a means to select the type of battery. Never use a controller that is not intended for your type of battery.
Typical set points for 12 V lead-acid batteries at 77° F (25° C)
(These are typical, presented here only for example.)
High limit (flooded battery): 14.4 V
High limit (sealed battery): 14.0 V
Resume full charge: 13.0 V
Low voltage disconnect: 10.8 V
Reconnect: 12.5 V
Temperature compensation for 12V battery:
-.03 V per ° C deviation from standard 25° C

Low Voltage Disconnect (LVD)

The deep-cycle batteries used in renewable energy systems are designed to be discharged by about 80 percent. If they are discharged 100 percent, they are immediately damaged. Imagine a pot of water boiling on your kitchen stove. The moment it runs dry, the pot overheats. If you wait until the steaming stops, it is already too late!

Similarly, if you wait until your lights look dim, some battery damage will have already occurred. Every time this happens, both the capacity and the life of the battery will be reduced by a small amount. If the battery sits in this over discharged state for days or weeks at a time, it can be ruined quickly.

The only way to prevent over discharge when all else fails is to disconnect loads (appliances, lights, etc.), and then to reconnect them only when the voltage has recovered due to some substantial charging. When over discharge is approaching, a 12-volt battery drops below 11 volts (a 24 V battery drops below 22 V).

A low voltage disconnect circuit will disconnect loads at that set point. It will reconnect the loads only when the battery voltage has substantially recovered due to the accumulation of some charge. A typical LVD reset point is 13 volts (26 V on a 24 V system).

All modern inverters have LVD built in, even cheap pocket-sized ones. The inverter will turn off to protect itself and your loads as well as your battery. Normally, an inverter is connected directly to the batteries, not through the charge controller, because its current draw can be very high, and because it does not require external LVD.

If you have any DC loads, you should have an LVD. Some charge controllers have one built in. You can also obtain a separate LVD device. Some LVD systems have a "mercy switch" to let you draw a minimal amount of energy, at least long enough to find the candles and matches! DC refrigerators have LVD built in.

If you purchase a charge controller with built-in LVD, make sure that it has enough capacity to handle your DC loads. For example, let's say you need a charge controller to handle less than 10 amps of charge current, but you have a DC water-pressurizing pump that draws 20 amps (for short periods) plus a 6 amp DC lighting load. A charge controller with a 30 amp LVD would be appropriate. Don't buy a 10-amp charge controller that has only a 10 or 15-amp load capacity!

Overload Protection

A circuit is overloaded when the current flowing in it is higher than it can safely handle. This can cause overheating and can even be a fire hazard. Overload can be caused by a fault (short circuit) in the wiring, or by a faulty appliance (like a frozen water pump). Some charge controllers have overload protection built in, usually with a push-button reset.

Built-in overload protection can be useful, but most systems require additional protection in the form of fuses or circuit breakers. If you have a circuit with a wire size for which the safe carrying capacity (ampacity) is less than the overload limit of the controller, then you must protect that circuit with a fuse or breaker of a suitably lower amp rating. In any case, follow the manufacturer's requirements and the National Electrical Code for any external fuse or circuit breaker requirements.

Displays and Metering

Charge controllers include a variety of possible displays, ranging from a single red light to digital displays of voltage and current. These indicators are important and useful. Imagine driving across the country with no instrument panel in your car! A display system can indicate the flow of power into and out of the system, the approximate state of charge of your battery, and when various limits are reached.

If you want complete and accurate monitoring however, spend about US$200 for a separate digital device that includes an amp-hour meter. It acts like an electronic accountant to keep track of the energy available in your battery. If you have a separate system monitor, then it is not important to have digital displays in the charge controller itself. Even the cheapest system should include a voltmeter as a bare minimum indicator of system function and status.

Have It All with a Power Center

If you are installing a system to power a modern home, then you will need safety shutoffs and interconnections to handle high current. The electrical hardware can be bulky, expensive and laborious to install. To make things economical and compact, obtain a ready-built "power center." It can include a charge controller with LVD and digital monitoring as options. This makes it easy for an electrician to tie in the major system components, and to meet the safety requirements of the National Electrical Code or your local authorities.

Charge Controllers for Wind and Hydro

A charge controller for a wind-electric or hydroelectric charging system must protect batteries from overcharge, just like a PV controller. However, a load must be kept on the generator at all times to prevent overspeed of the turbine. Instead of disconnecting the generator from the battery (like most PV controllers) it diverts excess energy to a special load that absorbs most of the power from the generator. That load is usually a heating element, which "burns off" excess energy as heat. If you can put the heat to good use, fine!

Is It Working?

How do you know if a controller is malfunctioning? Watch your voltmeter as the batteries reach full charge. Is the voltage reaching (but not exceeding) the appropriate set points for your type of battery? Use your ears and eyes-are the batteries bubbling severely? Is there a lot of moisture accumulation on the battery tops? These are signs of possible overcharge. Are you getting the capacity that you expect from your battery bank? If not, there may be a problem with your controller, and it may be damaging your batteries.

Conclusion

The control of battery charging is so important that most manufacturers of high quality batteries (with warranties of five years or longer) specify the requirements for voltage regulation, low voltage disconnect and temperature compensation. When these limits are not respected, it is common for batteries to fail after less than one quarter of their normal life expectancy, regardless of their quality or their cost.

A good charge controller is not expensive in relation to the total cost of a power system. Nor is it very mysterious. I hope this article has given you the background that you need to make a good choice of controls for your power system.

**B.2 Glossary of Solar-Electric Terms**

Courtesy of Dankoff Solar Products, Inc.
Santa Fe, NM USA

Basic Electricity

AC - Alternating Current, the standard form of electrical current supplied by the utility grid and by most fuel-powered generators. The polarity (and therefore the direction of current) alternates. In U.S.A., standard voltages for small water pumps are 115V and 230V. Standards vary in different countries. See inverter.

DC - Direct Current, the type of power produced by photovoltaic panels and by storage batteries. The current flows in one direction and polarity is fixed, defined as positive (+) and negative (-). Nominal system voltage may be anywhere from 12 to 180V. See voltage, nominal.

Current - The rate at which electricity flows through a circuit, to transfer energy. Measured in Amperes, commonly called Amps. Analogy: Flow Rate in a water pipe.

Efficiency - The percentage of power that gets converted to useful work. Example: An electric pump that is 60% efficient converts 60% of the input energy into work - pumping water. The remaining 40% becomes waste heat.

Energy - The product of power and time, measured in Watt-Hours. 1000 Watt-Hours = 1 Kilowatt-Hour (abbreviation: KWH). Variation: the product of current and time is Ampere-Hours, also called Amp-Hours (abbreviation: AH). 1000 watt consumed for 1 hour = 1 KWH. See power.

Converter - An electronic device for DC power that steps up voltage and steps down current proportionally (or vice-versa). Electrical analogy applied to AC: See transformer. Mechanical analogy: gears or belt drive.

Inverter - An electronic device that converts low voltage DC to high voltage AC power. In solar-electric systems, an inverter may take the 12, 24, or 48 volts DC and convert it to 115 or 230 volts AC, conventional household power.

Power - The rate at which work is done. It is the product of Voltage times Current, measured in Watts. 1000 Watts = 1 Kilowatt. An electric motor requires approximately 1 Kilowatt per Horsepower (after typical efficiency losses). 1 Kilowatt for 1 Hour = 1 Kilowatt-Hour (KWH).

Transformer - An electrical device that steps up voltage and steps down current proportionally (or vice-versa). Transformers work with AC only. For DC, see converter. Mechanical analogy: gears or belt drive.

Utility Grid - Commercial electric power distribution system. Synonym: mains.

Voltage - The measurement of electrical potential. Analogy: Pressure in a water pipe.

Voltage Drop - Loss of voltage (electrical pressure) caused by the resistance in wire and electrical devices. Proper wire sizing will minimize voltage drop, particularly over long distances. Voltage drop is determined by 4 factors: wire size, current (amps), voltage, and length of wire. It is determined by consulting wire sizing chart or formula available in various reference texts. It is expressed as a percentage. Water analogy: Friction Loss in pipe.

Voltage, Nominal - A way of naming a range of voltage to a standard. Example: A "12 Volt Nominal" system may operate in the range of 11 to 15 Volts. We call it "12 Volts" for simplicity.

Solar Electricity

Photovoltaic - The phenomenon of converting light to electric power. Photo = light, Volt = electricity. Abbreviation: PV. PV - The common abbreviation for photovoltaic.

PV Array - A group of PV (photovoltaic) modules (also called panels) arranged to produce the voltage and power desired.

PV Array-Direct - The use of electric power directly from a photovoltaic array, without storage batteries to store or stabilize it. Most solar water pumps work this way, utilizing a tank to store water.

PV Cell - The individual photovoltaic device. The most common PV modules are made with 33 to 36 silicon cells each producing 1/2 volt.

PV Module - An assembly of PV cells framed into a weatherproof unit. Commonly called a "PV panel". See PV array.

Solar Tracker - A mounting rack for a PV array that automatically tilts to follow the daily path of the sun through the sky. A "tracking array" will produce more energy through the course of the day, than a "fixed array" (non-tracking) particularly during the long days of summer.

Voltage, Open Circuit - The voltage of a PV module or array with no load (when it is disconnected). A "12 Volt Nominal" PV module will produce about 20 Volts open circuit. Abbreviation: Voc.

Voltage, Peak Power Point - The voltage at which a photovoltaic module or array transfers the greatest amount of power (watts). A "12 Volt Nominal" PV module will typically have a peak power voltage of around 17 volts. A PV array-direct solar pump should reach this voltage in full sun conditions. In a higher voltage array, it will be a multiple of this voltage. Abbreviation: Vpp.

## B.3 Batteries: How to keep them alive for years and years

Lead-acid batteries are often considered to be the "weak link" in renewable energy systems. However, today's renewable energy batteries are better than ever, and so are the devices that regulate and protect them. Battery failures are rarely the fault of the batteries themselves! Follow these guidelines to avoid the vast majority of all battery problems.

Size a battery bank and PV array properly

A battery bank should be sized (as a minimum) to a capacity of 5 days of load. Energy use in most home power systems increases over time, so consider sizing larger than that. Why? After 1 year of service, it is NOT advisable to enlarge a battery bank by adding new batteries to it, because batteries' voltage response changes with age. Stray currents flow, causing losses and failure to equalize. A PV array, if it is the primary energy source, should be sized to produce (on average) 30% more energy than the load requires. This compensates for battery losses and for less-than-average charging conditions. Luckily, a PV array can be expanded at any time.

Buy high-quality batteries, selected for your needs

You get what you pay for! Good deep-cycle batteries can be expected to last for 5 to 15 years, and sometimes more. Cheap batteries can give you trouble in half that time. Buy from a reputable source.

Avoid multiple parallel strings

The ideal battery bank is the simplest, consisting of a single series of cells that are sized for the job. Higher capacity batteries tend to have thicker plates, and therefore greater longevity. Having fewer cells will reduce the chance of randomly occurring defects, and reduces maintenance. Suppose for example, that you require a 700 Amp-Hour bank. You can approximate that by using 3 parallel strings of golf-cart batteries (220 AH), or 2 strings of the larger L-16 style batteries (350 AH) or a single string of larger, industrial batteries.

Under no circumstances is it advisable to install more than three parallel battery strings. The resulting bank will tend to lose its equalization, resulting in accelerated failure of any weak cells. Weak cells will be difficult to detect because they will "steal" from the surrounding cells, and the system will suffer as a whole and will cost you more in the long run.

Here are some precautions to take when wiring two or more strings of batteries in series-parallel. The goal is to maintain all of the cells at an equal state of charge. Cells that tend to receive less charge are likely to fail prematurely. This can take years off the effective life of the battery bank. A fraction of an ohm of added resistance in one battery string can reduce the life of the entire string.

(1) Connect the two main cables to opposite corners of the battery bank, and maintain symmetry in wire size and lengths. This will help to distribute current evenly through the bank.

(2) Arrange batteries to maintain even temperature distribution throughout the bank. Avoid uneven exposure to heat sources. Leave at least 1/2 inch of air space around each battery, to promote even cooling.

(3) Apply a finish charge at least every 3 weeks (bring every cell to 100% charge).

Prevent corrosion

In flooded battery installations, corrosion of terminals and cables is an ugly nuisance that causes resistance and potential hazards. Once corrosion gets hold, it is hard to stop. The good news -- it is easy to prevent! Apply a non-hardening sealant to all of the metal parts of the terminals BEFORE ASSEMBLY. Completely coat the battery terminals, the wire lugs, and the nuts and bolts individually. A sealant applied after assembly will not reach all around every junction. Voids will remain, acid spatter will enter, and corrosion will begin as soon as your installation is finished.

Special compounds are sold to protect terminals, but you can have perfectly good results using common petroleum jelly (Vaseline). It will not inhibit electrical contact. Apply a thin coating with your fingers, and it won't look sloppy. If wire is exposed at a terminal lug, it should be sealed airtight, using either adhesive-lined heat-shrink tubing or submersible rubber splice tape. You can also seal an end of stranded wire by warming it gently, and dipping it in the petroleum jelly to liquefy, and wick it into the wire.

It also helps to put the batteries over a floor drain, or in a space without a floor, so that they can be rinsed with water easily. Washing the battery tops (about twice per year) will remove accumulated moisture (acid spatter) and dust. This will further reduce corrosion, and will prevent stray currents from stealing energy. Batteries that we have protected by these measures show very little corrosion, even after 10 years without terminal cleaning.

Moderate the temperature

Batteries lose approximately 25% of their capacity at a temperature of 30°F (compared to a baseline of 77°F). At higher temperatures, they deteriorate faster. Thus, it is desirable to protect them from temperature extremes. If no thermally stable structure is available, consider an earth-sheltered enclosure. Where low temperature cannot be avoided, get a larger battery bank to make up for the loss of capacity in the winter. Avoid direct radiant heat sources that will cause some batteries to get warmer than others.

Use temperature compensation

When batteries are cold, they require an increase in the charge voltage limit, in order to reach full charge. When they are warm, they require a reduction in the voltage limit in order to prevent overcharge. Temperature compensation is a feature in many charge controllers and power centers, as well as in the back-up chargers in some inverters. To use this feature, order the accessory temperature probe for each charging device, and attach it to any one of the batteries.

Use low-voltage disconnects

Discharging a battery to exhaustion will cause immediate, irreversible loss of capacity and life expectancy. Your system should employ low voltage disconnect (LVD) in the load circuits. Most inverters have this feature, and so do many charge controllers and power centers. Don't depend on human behavior to prevent over-discharge. It can be caused easily by accident or by an irresponsible user. Again, most inverters have LVD built-in but if there are DC loads on the system, please incorporate an LVD device.

Bring batteries to a full state-of-charge at least every 3 weeks

Bring the batteries to a full state-of-charge (SOC) at least every 3 weeks. This reduces internal corrosion and degradation, and helps to insure equalization, so that any weaker cells do not fall continually farther behind. A full SOC may occur naturally during most of the year, but do not hesitate to run a generator when necessary, to bring the batteries up. Information like this should be posted at the power center. For more details, refer to the instructions for the inverter/charger and for the batteries.

- How do you know when a battery is 100% charged?

The "charged" indicator on most PV charge controllers means only that battery voltage is relatively high. The SOC may be approaching full, but is not necessarily near 100% a voltmeter reading gets you closer, but it is not a certain indicator. It varies too much with current flow, temperature and time, to give a clear indication.

For flooded batteries, a hydrometer is the definitive indicating device, although not a convenient one. With it, you can measure every cell individually. Obtain one from a battery or automotive supplier. Even the cheapest hydrometer is fine. Rinse it after use, and keep it clean.
An amp-hour meter is the most informative and user-friendly way to monitor SOC. For sealed batteries, it

is the ONLY definitive method. See next paragraph.

Install a System Monitor

Would you drive a car with no dashboard? Metering is not just "bells and whistles". It is necessary to help you to read the status of the system. Many charge controllers have indicator lights and readouts built-in. For a full-scale remote home, consider the addition of a digital monitor, like Trace TM-500, Tri-Metric, E-Meter or Omni-Meter. These devices monitor voltage and current, record amp-hours, and accurately display the state-of-charge of the battery bank. They also record more detailed information that can be useful for troubleshooting. The monitor may be mounted in another room or building, for handy viewing.

How to Read a Hydrometer

A hydrometer will help you to determine whether the battery bank is getting fully charged, and whether any individual cells are falling behind. You should be aware that a hydrometer will give you false readings under the following conditions.

(1) After adding water: For pure water to mix throughout the cell, it takes time and some bubbling during finish charge. A hydrometer will show a greatly reduced reading until the fluid mixes.

(2) Low temperature: As battery temperature drops, the fluid becomes more dense. A temperature compensating hydrometer is best. Otherwise, for every 10°F below 70°F, subtract 3.5 points from the reading.

(3) Time lag during recharge: As the battery recharges, the fluid becomes denser down between the plates. The hydrometer reads the fluid above the plates. You will get a delayed reading until the fluid is mixed by the movement of bubbles during finish charge. The voltage will rise steadily, providing an indication that something is happening.

During discharge, you will get a true hydrometer reading because the fluid becomes less dense and will circulate to the top. Any time a hydrometer indicates a fully charged cell, you KNOW it is fully charged.

WARNING

BATTERY ACID IS HAZARDOUS. When working around batteries, wear safety glasses. Get a rugged plastic bottle to keep with your service tools, and fill it with a sodium bicarbonate (baking soda) and water. Use it to neutralize accidental splash or spills and to clean normal acid spatter from battery tops. Finally, don't wear your favorite blue jeans!

Just add water

Note: This applies only to "flooded batteries", not to "sealed batteries". The plates of every cell in your battery bank must be submerged at all times. Never add any fluid to a battery except distilled water, deionized water, or very clean rainwater collected in plastic containers. Most batteries require addition of water every 6 to 12 months. There is no need to fill them more frequently than needed to submerge the plates. Fill them only to the level recommended by the manufacturer, generally about an inch below the top, otherwise they may overflow during finish-charging.

Conclusion

Batteries are the heart of your power system. They may demand your attention occasionally, but your relationship with them need not be a struggle. With a proper installation, a little understanding and some simple maintenance, your batteries will live a long and healthy life.

62

## B.4 Troubleshooting a PV Array

by Windy Dankoff

Photovoltaic modules are so reliable that we forget that things can go wrong! The real world imposes temperature extremes, lightning and static electricity, moisture and wind stresses, as well as imperfect manufacturing. Here are some suggestions for testing and troubleshooting.

Selective shading test - If the array is in a parallel or series-parallel configuration, this trick will help you locate a fault without disconnecting any wiring. Find an object that is large enough to shade at least 4 cells. (A cowboy hat will do.) Shading just a few cells will drop the module's output to less than half. With the array connected and working, monitor the current (or in the case of a nearby solar pump, just listen to it). Now, shade a portion of one module. You should see the current should drop noticeably (or the pump should slow down). If the current does NOT drop, then the module that you are shading is out of the circuit. Look for a fault in the wiring of that module, or of another module that is wired in series with it.

Fading in the heat

Occasionally somebody complains of reduced array output when the sun is hottest. Heat fade shows up most severely in battery systems. If the difference between the array voltage and the battery voltage approaches zero, then current flow can drop nearly to zero. This can also cause a solar pump to produce less than it should.

The voltage of a PV module normally decreases with temperature rise. PV manufacturers document this by showing several lines on the IV curve (the graph of amps vs. volts), or by stating it in volts per degree of deviation from 25°C (77°F). Nominal "12 volt" PV modules are designed to sustain good current flow all the way to 17 or 18V at 25°C. This allows for voltage drop at higher temperatures. If heat fade is severe, it MAY be caused by weak PV modules or by any other weak links in the power chain, including undersized wiring, poor connections and controller losses. Here are some tests to isolate these factors.

First, you can confirm heat fading by cooling the array with water while the system is operating. Monitor the current. Does it rise to normal? If so, you need to determine where the voltage drop is severe. Connect a voltmeter directly to the PV array (or it's combiner box). Disconnect the array from the controller, in order to read the open circuit voltage. If it is less than 18V (relative to a 12V configuration), then part or all of the PV array may be defective. The selective shading test (above) can help you locate weaker modules in an array.

Next, reconnect the array to the system. Under good sunlight, test for voltage drop in the wiring by measuring the voltage at the array, and then again at the controller input. Note that voltage drop in wiring will increase in proportion to the current flow. Next, test for drop in the controller by measuring the voltage at its PV input, and then at its battery terminals. Remember, if the battery is fully charged, the controller SHOULD drop the voltage. If that is the case, you can bring down the battery voltage by turning loads on. When the battery is at less than 13.5V (relative to a 12V system), the controller should allow full current to flow.

If voltage drop occurs at a single point (at a connector or within the controller) then concentrated heat will result. You may feel it, or see signs of heat damage. If voltage drop is evident at the loads (dimming lights, low voltage disconnection when batteries are not low) then check for corroded battery connections (see "Batteries: How to Keep Them Alive" in Sun Paper 1, or at our website).

Burnt terminals

Years of temperature cycling will occasionally cause a screw to loosen, or metal to distort. This can be caused by poor workmanship and/or inferior materials. Add a touch of oxidation and corrosion, and you get electrical resistance. Now, keep the current flowing and you get even more heat. When you repair overheated connections, replace all metal parts that have been severely oxidized. In worst cases, an electric arc will jump a gap, melting metal and burning insulation to a char. Charred terminals on PV modules can be bypassed by soldering a wire directly to the metal strip that leads to the PV cells.

Diode failures

Most PV modules have bypass diodes in the junction boxes, to protect cells from overheating if there is a sustained partial shade on them. On rare occasions, a diode will fail, usually as a result of lightning. Most often, it will short out and reduce the module's voltage drastically. (A shorted diode will read near-zero ohms in both directions.) If the module is in a 12V array, there is no need for the bypass diode so you can remove it. In a 24V array that is unlikely to experience sustained partial shading, you can remove it. In any other case, replace it with a silicon diode with an amps rating at or above the module's maximum current, and with a voltage rating of 400V or more.

## B.5 Surviving Winter with a PV Power System

by Windy Dankoff, Dankoff Solar Products

The winter season puts photovoltaic systems to the test. The electrical demands are highest while the least amount of sunshine is available. Here are some suggestions for maintenance, plus some tricks-of-the-trade to minimize or eliminate the use of a backup generator.

CHECKLIST

PHOTOVOLTAIC ARRAY: Inspect/tighten mounting bolts & wiring, test output, tilt for winter angle.

TRACKERS: oil bearings, check mounting bolts and shock absorber action.

GAS GENERATORS, WIND GENERATORS: Consult the supplier or instruction manual.

BACKUP CHARGING SYSTEM: Be sure that it is wired, tested and ready in advance.

CHARGE CONTROLLER: Check regulator voltage settings, check voltmeter accuracy with digital meter. If batteries may have reached a temperature below 55°F, they should be allowed to rise to a higher voltage (14.8V min. on a 12V system). If your charge control has a "temperature compensation" feature, then this will happen automatically. If it has an external temperature sensor, be sure that it is attached to a battery. If it does not have this but is adjustable, you may raise the voltage by hand, and lower it again in the Spring (to 14.3V). If your controller is not adjustable, keep the batteries warmer.

BATTERIES (Lead-Acid types): Test each cell/each battery with digital voltmeter or hydrometer to spot potential failures and check need for equalization. Set up equalization charge if necessary (typically, an 8-hour moderate overcharge after the batteries have reached full charge). Wash away accumulated moisture and dust from battery tops (use baking soda solution to neutralize acid deposits). Clean, or replace corroded terminals. Coat all terminal components with petroleum jelly, preferably while they are disassembled. This will prevent future corrosion. Check water levels & refill with distilled or deionized water. Inspect venting (check for insect nests in vent pipes).

WIRING: Check for proper wire sizing, tight connections, fusing, safety.

GROUNDING/LIGHTNING PROTECTION: Install/inspect ground rods and connections, ground wiring.

LOADS/APPLIANCES: Check for "phantom loads" and inefficient usages. Examples: Wall cube transformers and TVs with remote control that use power all the time they plugged in. Does your furnace thermostat hold your inverter on 24 hrs/day? -- See below!

LIGHTS: Look for blackening incandescent bulbs, consider more efficient Halogen or fluorescent replacements. Replace blackened fluorescents. Clean the dust from light bulbs and fixtures.

INVERTERS: Check adjustments, settings, connections. NOTE: Inverters with battery charging function should have charge voltage set around 14.5 (or 29) volts if a generator is to be used for charging. See your manual. Add accessory temperature probe if appropriate.

WATER SUPPLY: Check freeze-protection, pump maintenance, pressure tank pre-charge.

BATTERY TEMPERATURE

Lead-Acid storage batteries lose about 25% of their storage capacity at 30°F. If fully discharged, they can freeze at 20°, and be destroyed. Summer heat is also destructive. For these reasons batteries should be protected from outdoor temperature extremes. Batteries can be safe indoors, if installed in accordance with the National Electrical Code.

FREEZE PROTECTION & HEAT TAPES

Electric heat tapes are a popular way to prevent water pipes from freezing under mobile homes, on solar water heaters, in well sheds and other places where they may be exposed to cold. Where heat tapes are a necessary evil, follow these tips to MINIMIZE THEIR ENERGY USAGE:

INSULATE!!! Use foam pipe jacketing, fiberglass, ANYTHING that insulates, and PLENTY OF IT! Be sure cold air and moisture are sealed out.

USE LESS HEAT TAPE than recommended, with fewer, wider-spaced coils. With extra insulation, you won't need much heat.

USE AN INVERTER that is efficient for running SMALL loads like your heat tape. Or, consider the following.

CONVERT HEAT TAPES TO 12 OR 24 VOLTS! If you're not afraid to cut and splice, here's how to make a low voltage heat tape:

Buy a conventional FLAT heat tape.

(2) For 12V, measure 1/10 of its length from the thermostat end and CUT. For 24V, use 1/5 of its length.

(3) Strip the cut end and connect the two inner wires together using the barrel of a crimp terminal. Be careful, the wires are thin and delicate. Protect the end with silicone sealant and/or tape.

You now have a low voltage tape. It will draw the same wattage PER FOOT as the original. The thermostat (if present) will work, but the neon indicator light won't. The remaining tape may be cut into more low voltage tapes by splicing lamp cord to one end, and tying the other end together (using crimp connectors). Add an external thermostat* because heat tape thermostats sometimes turn on as high as 50°. One line voltage thermostat can switch several tapes on and off.

FURNACES AND CONTROLS

THERMOSTAT CIRCUITS and POWER USAGE: Most central heating systems use a low voltage circuit through a wall thermostat, to tell the furnace when to turn on and off. The low voltage is derived from a small transformer, which is powered constantly. It consumes only a few watts, but in an alternative energy system that may be a significant load -- if it is the only AC device that's running, it is adding constant additional draw just to keep the inverter "up". That amounts to the wintertime energy output of 1 or 2 PV panels, costing over $300 each, plus battery capacity to match!

If yours is a system where the inverter spends most of its time turned off (relatively little AC power usage) it is worth the small modification of adding a line voltage thermostat * to your furnace circuit. Have it installed IN THE AC LINE to the furnace controls. (Also bypass the original thermostat.) This way when heat is not needed, all power is cut to the furnace transformer. A small "limit switch" thermostat may also be added to sense heat in the furnace and keep the blower on until residual heat is exhausted. Material cost of these modifications is under $50 and the wiring is simple.

LOW TEMPERATURE SETTING: When nobody's home, you may need your furnace only to prevent your home from reaching freezing temperature (so that water pipes, fixtures and bottles won't freeze). Most heating thermostats stop at 55°F, but a lot of fuel may be saved if the temp can be lowered to 40°. or less. Electric power is saved too, since the furnace blower will run much less. The thermostat listed below will set down to 40°.

CONCLUSION

Being your own power company has its rewards AND its responsibilities. Extra attention paid in preparation for winter time will reward you with greater energy independence for years to come. If you are uncertain about working on your system, contact your dealer or a qualified electrician.

* A "line voltage thermostat" is one that is designed to handle power directly from 120 vac. An example is Honeywell T498A1778 available from W. W. Grainger, stock #2E831. It has a 40°-80°F range.

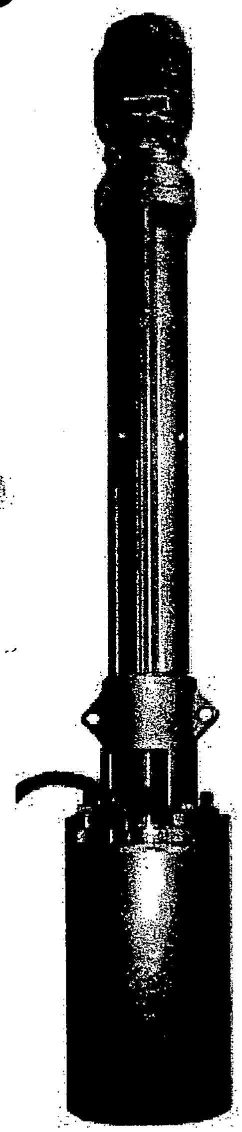
# B.6 ETAPUMP® Solar Water Pump and ETAPUMP Integrated System™ Instruction Manual

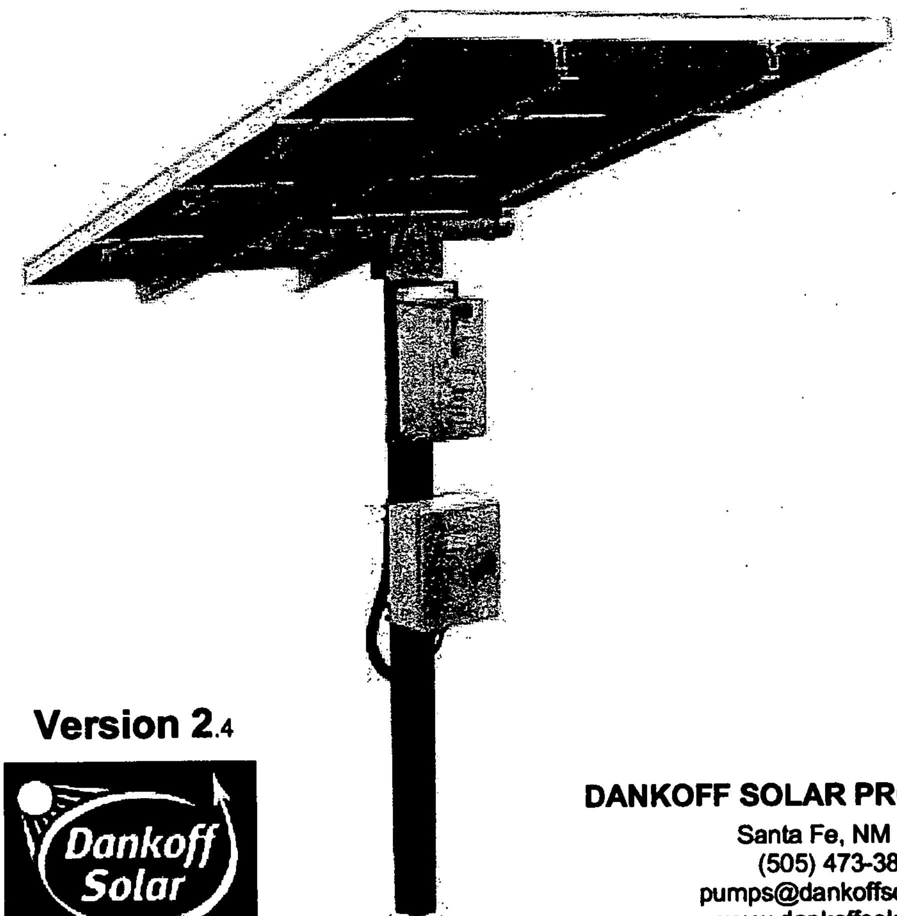
# ETAPUMP®

# Solar Water Pump

and *ETAPUMP Integrated System™*

# INSTRUCTION MANUAL





**Version 2.4**

**DANKOFF SOLAR PRODUCTS, INC.**

Santa Fe, NM USA
(505) 473-3800
pumps@dankoffsolar.com
www.dankoffsolar.com

# WARNINGS

Failure to follow these instructions will void the warranty.

| | |
|---|---|
| ⚠ | Open circuit (no-load) voltage above 100V will destroy the controller. This may occur if the wrong PV modules (solar panels) are used, or if the solar array is incorrectly wired. Measure the array voltage before connecting to the controller. A "48V" (nominal) array should produce an open circuit voltage around 75-90V under any daylight conditions. (See Solar Array Wiring, Section 5.3) |
| ⚠ | Do not attempt to run the ETAPUMP Motor without the ETAPUMP controller. Do not attempt to use ETAPUMP controller for any purpose other than ETAPUMP. |
| ⚠ | To be installed, connected and serviced by qualified personnel only. Ensure all power sources are disconnected when making connections to this unit. Follow all appropriate electrical codes. There are no user serviceable parts inside the motor or the controller. |
| ⚠ | Solar pumps run at low flow rates, and have closer tolerances than conventional pumps. Extreme sand or silt concentration (greater than 2% by volume) may cause the pump to stop, or the pipe to fill with sand. Do not use *ETAPUMP* to clean out a dirty well. (See Section 6.6.) |
| ⚠ | Helical rotor pumps are sensitive to heat. Protect the pump from sunshine or other source of heat, or it may lock temporarily. If the water source is, or will be warmer than 72° (22°C), a special model may be required. See Section 6.4. |
| ⚠ | Undersized wire will cause failure to start. See Section 5.7. |
| ⚠ | Install proper system grounding for safety and lightning protection (See Section 5.2) |
| ⚠ | Do not touch the controller input or pump wires together to test for a spark. |
| ⚠ | Do not run the pump dry. Exception: to test direction of rotation, for maximum 15 seconds (See Section 5.8) |
| ⚠ | Test the direction of motor rotation before installing the pump (counter-clockwise looking down). If direction is reversed, exchange the connection of any two of the three power wires to the pump. (See Section 5.8) |
| ⚠ | If pump has a brass check valve, do not connect galvanized steel pipe directly to the pump without using a dielectric (insulated) connection. (See Section 6.2) |
| | When pump is stopped by a shadow or by action of float switch, it will restart after a 30- 90 seconds. |
| | The low water probe must be submersed, or the pump will stop for 20 minutes. If the probe is not to be used, connect the probe terminals together in the junction box. (See section 5.5 and 5.9) |
| | Helical rotor models (without a C in the model #) are not self-draining. Do not remove the check valve in attempt to make it self-drain. If drainage is required for freeze-protection, install a weep hole or draining device below freeze level. See Section 13.6 |

Installation should be in accordance with local regulations and accepted codes of good practice.
**This manual is the property of the *ETAPUMP* owner.**
Please give it to the owner or maintenance personnel when you are finished!
Request copies from your *ETAPUMP* supplier or download from www.dankoffsolar.com

This manual is for controller models EP600A, EP600AB, ME24/48A
as illustrated on the cover. For earlier models (before July 2003) refer to Version 1

---



Version 2.4A September 9, 2003



70

# 2 SYSTEM REPORT FORM

**This data may be needed for future maintenance.**

## System and Components

*ETAPUMP Integrated System*™ Number ETA - ____ - ____
(Most non-battery *ETAPUMP* are sold with a complete system)

System Voltage ________ Date of Purchase ___________

Purchased from ________________

Battery System? ________ or Quantity of Solar Modules (panels) _______

Solar Module Brand ____________ Module Model # _______

Controller Model: [ ] EP600A (solar-direct only)
[ ] EP600AB (battery only) [ ] ME24/48A (battery only) [ ] other ___________

Controller Serial # _____________

Pump End Model # _________ Pump End Serial # ______

**Temperature Range** HR...-X *X indicates temperature class*

Helical rotor pumps (without C in the model number) work optimally only in a specific range of temperature. If a special temperature range was not specified, the last digit of model number (X) will be 1.

| | | | |
|---|---|---|---|
| Class 0 | 32°F to 54°F | (0°C to 12°C) | |
| Class 1 | 46°F to 72°F | (8°C to 22°C) | ← **Class 1 is the standard class.** |
| Class 2 | 64°F to 90°F | (18°C to 32°C) | |
| Class 3 | 82°F to 108°F | (28°C to 42°C) | See Section 12 for more about temperature specifications. |
| Class 4 | 100°F to 126°F | (38°C to 52°C) | |

## Installation Report

Installation Date ___________ by: ____________________

Well Depth ______ [ ] feet [ ] meters Pump depth ___________

Additional Vertical Lift (up to top of tank) __________

Static Water Level _________ Variable? ____________

Drop Pipe (vertical from the pump)
Size ________ Type ___________ Length __________

Additional Pipe Length (to tank)
Size ________ Type ___________ Length __________

Submersible Pump Cable
Wire size ________ Total Length (controller to pump) __________

## Performance Report

When the pump is operating, record this data. This will help you to assess its performance and diagnose any problems that may occur in the future.

Flow rate observed ______ [ ] GPM [ ] lpm Notes: _________________

AC current through any one pump wire (See Section 13.7) ______ Amps

If these measurements were not taken at full vertical lift, note here: _______________



71

# TABLE OF CONTENTS





72

# 3 INTRODUCTION

**Thank you for purchasing *ETAPUMP*®** *ETAPUMP* sets a new standard for quality and economy in solar pumping. It incorporates the best solar pump technologies that were very expensive in the past. *ETAPUMP* is engineered in Germany and made in China at a German-owned high technology factory. Key components of the pump are made in Germany. It is imported for the Americas by Dankoff Solar Products, a pioneering solar pump developer since 1983.

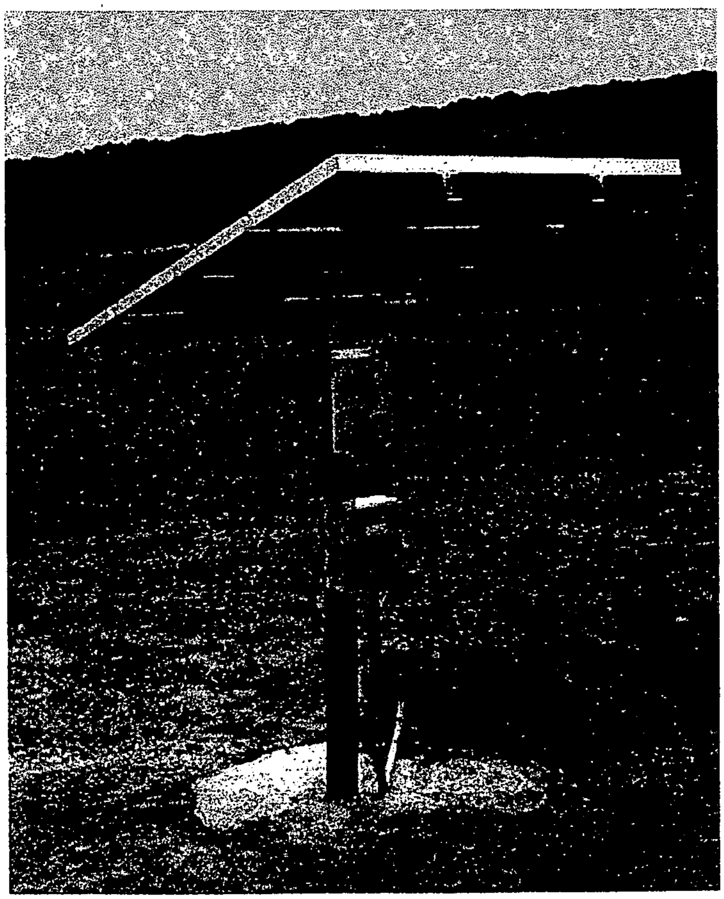
**Before you begin** Check the model numbers of all the components of your system, and verify that they are the items that you ordered. Also check against the *ETAPUMP* specifications and performance charts (end of this manual) to be sure the system is appropriate for your application. If you expect to pump water that is near-freezing or very warm, check the "temperature range" specifications (Section 12). If you think you have the wrong pump for your application, call your supplier immediately.

**Please fill in the SYSTEM REPORT** on page 3. This will be essential information if any problems occur.

**This manual covers two types of systems, battery and solar-direct.** If you purchased *ETAPUMP* to connect to a battery system, you can skip the sections about the solar array and solar-direct systems.

**System Wiring Diagram (solar-direct only)** If your pump was purchased as part of an *ETAPUMP INTEGRATED SYSTEM*™, a System Wiring Diagram should be attached at the back of this manual. Be sure the diagram is the correct one for the system you have.

**REFERENCE SECTION (Section 13)** Most *ETAPUMP* installers are new to solar pumping, so we provide helpful information—principles of operation, instructions for wellhead assembly, water storage, control and monitoring of water supply, pipe sizing, freeze protection, and a glossary of technical terms.



## *ETAPUMP* PHOTO GALLERY

**A MODEL INSTALLATION**

ETA-04-300 solar-direct system
Colorado, USA

This system was installed by students in a solar water pumping class.

The array is set at summer tilt angle.

The controller is mounted on the north side of the pole, directly under the array. This shades it from the hot mid-day sun.

Mounting and ground-bonding details are shown in Section 5.1.

Electrical conduit runs from the *ETAPUMP* junction box to the wellhead to protect the pump wires. The water pipe is all under ground.

Courtesy of Solar Energy International, Carbondale, CO, USA

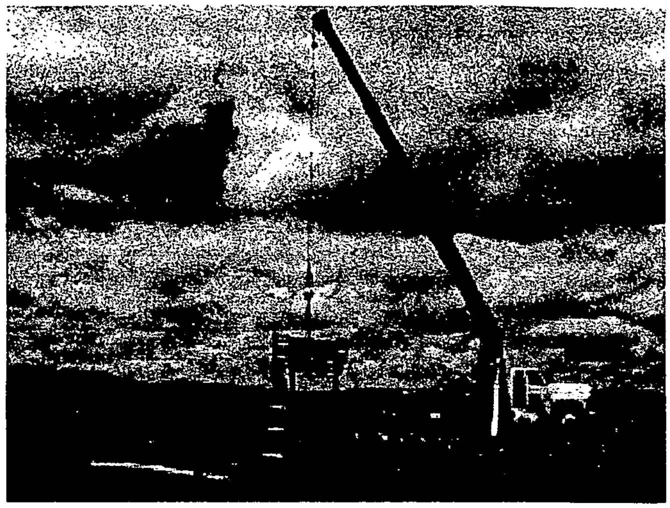


73

# *ETAPUMP* PHOTO GALLERY

Setting an array pole in concrete.

Courtesy of RA Power, Colorado USA

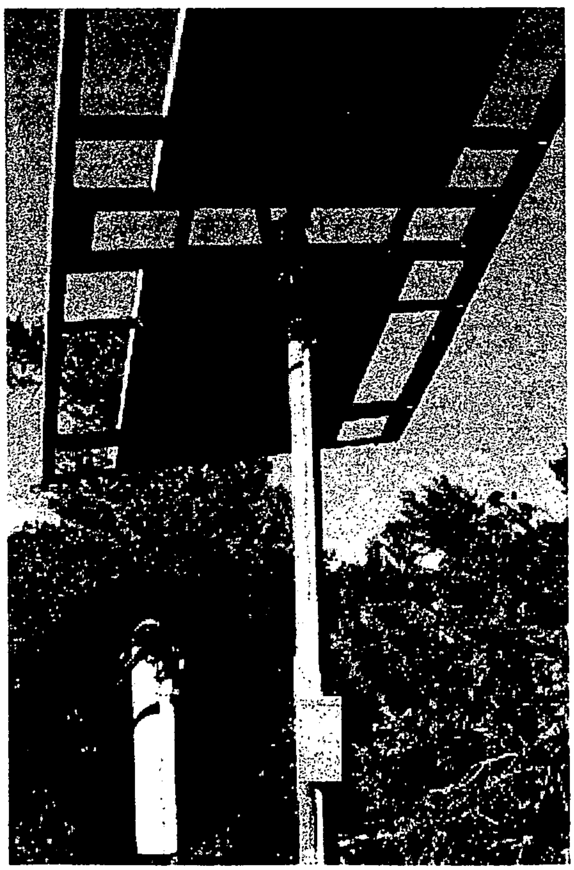


This PV array was assembled and wired on the ground, then lifted with a crane.

Courtesy of Skyline Solar, Idaho, USA

ETA-300 PV array assembly
The mounting pole is short enough to facilitate assembly without mechanical assistance.

Courtesy of Home Power Magazine



← A tracking solar array

The mounting pipe was extended to 11 feet (3m), by welding it to a larger pipe. Wire is type USE (outdoor rated). The wire is looped to help it to shed water and to flex. Wires enter the conduit through a "weather head".

Courtesy of Windy Dankoff, Santa Fe, NM

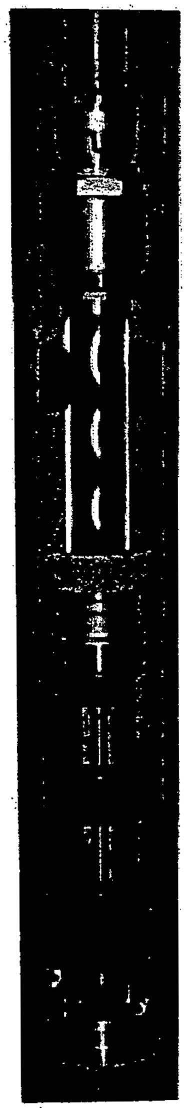
# *ETAPUMP* PHOTO GALLERY

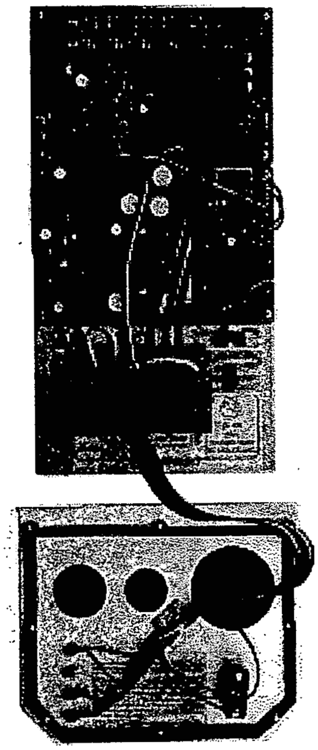
← ETA-04-300 system in Colorado, USA, installed by students in a solar pumping class.

The drop pipe is 3/4" polyethylene. Hand installation requires caution and is not always recommended (see Section 7.3)

Courtesy of Solar Energy International, Carbondale, CO, USA

Cutaway display of a helical rotor *ETAPUMP* in a well casing →





EP-600 controller, inside view.

← Owners of a domestic water system watch as *ETAPUMP* fills their polyethylene storage tank. The tank was buried later.

Photo courtesy of Home Power Magazine. Installation by Eastern Oregon Solar-Electric, Prineville, Oregon



75

# 4 INSTALLING THE SOLAR ARRAY

## 4.1 Location of the Solar Array

Sunlight is the "fuel" that drives a solar pump. Full solar exposure of the solar array is critical for full performance of a solar-direct system.

Choose a location for the solar array that has unrestricted sun exposure through the day and through the year. The array can be placed several hundred feet (100 m) or more from the wellhead. There will be no loss of performance if the electrical wire is sized properly, but naturally, the cost of wire will increase significantly. The *ETAPUMP* System Sizing Table specifies wire size requirements for both normal and extended wire lengths.

**CAUTION Shading a small portion of a PV array may cause the pump to stop completely.**

Each PV module (panel) contains a series of solar cells (typically 36 or 72 cells). Every cell that is shaded acts like a resistor, reducing the output of the ENTIRE ARRAY. Shading just a few cells will reduce the power disproportionately, and may stop the pump. Consider this when deciding where to install the array.

To determine where shadows may be cast at any time of the year, you can survey the site with a *Solar Pathfinder®*. This device is especially useful in forested areas or wherever there are obstructions nearby. It is available directly from Solar Pathfinder (USA) tel. (317) 501-2529, fax (931) 590-5400, www.solarpathfinder.com.

Place the bottom edge of the array at least 2 feet (.6 m) above ground to clear rain spatter, growing vegetation and snow. Keep in mind that trees and perennial plants will grow taller in the coming years.

## 4.2 Solar Array Assembly Methods

**WARNING Use extreme caution when assembling the array above your head.** You will work with a large and heavy assembly and unpredictable wind. The use of ladders can be dangerous.

There are two ways to install the solar array. See PHOTO GALLERY for examples.
1. Assemble the array on the ground, wiring and all, then lift the entire assembly onto the pole or roof. A system of 300 watts or more may require the assistance of a backhoe, boom truck or crane to lift it over the pole.
2. Assemble the array piece-by-piece on the pole. If the pole is higher than about 6 feet (2m), it is best to construct a temporary platform, like a scaffold assembly commonly used in building construction). A scaffold system can be rented from a local supplier.

## 4.3 Solar Array Mounting Rack

**WARNING Your mounting structure must be engineered for wind resistance, and safety.**

**Follow the rack manufacturer's instructions that are packed with your rack.**

**Solar Tracking** A solar tracker is a special pole-mounted solar array rack that tilts automatically to follow the daily path of the sun. In clear summer weather, it can increase your daily water yield by 40-50%. (It is much less effective in winter and in cloudy weather.) A tracker is an option with *ETAPUMP* Integrated Systems™.

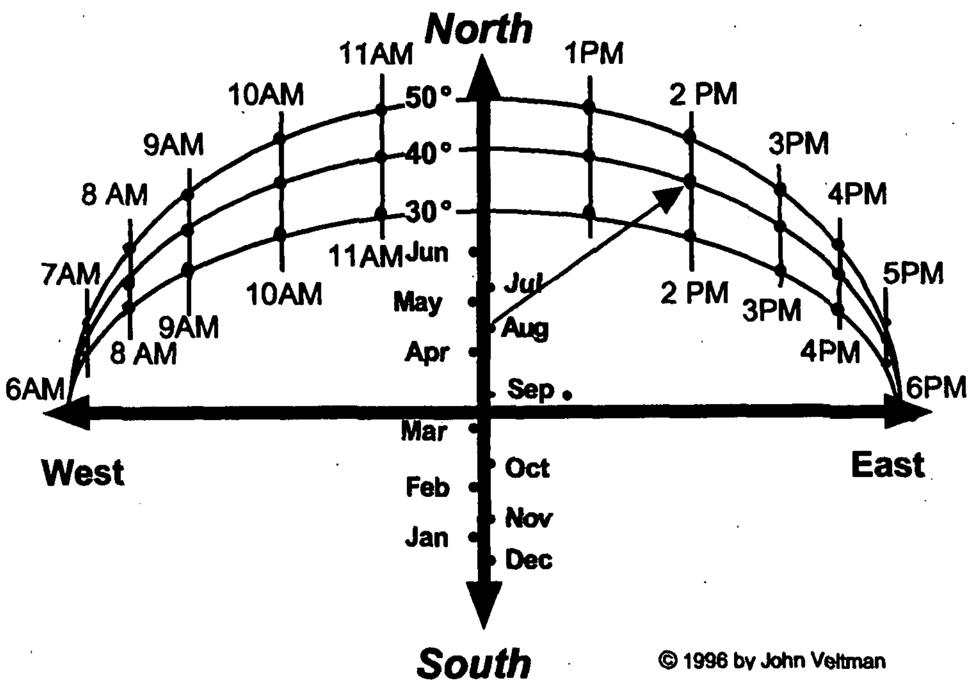
## 4.4 Orienting the Solar Array to Solar South

For full performance, your solar array must be oriented within 10° of true (solar) south. Depending on your location, a compass reading may show an error of as much as 20°. To correct this discrepancy, apply the magnetic declination for your region. Many regional maps indicate the magnetic declination. If you don't have a compass but can see your shadow and know the time of day, use the ***Sun Compass™***.

### *Sun Compass™*

For the USA (lower 48 states) and other 25° to 55° North latitude regions.

***Find True South*** quickly and accurately using only your shadow. No magnetic compass needed!




**Sun Compass Instructions**

1. Draw an arrow from Month dot to intersection of your <u>Standard</u> Time and Latitude. (The gray line is an example: August, 2 PM at 40° N lat.)
2. Stand and face your shadow.
3. Hold this page horizontally.
4. Point the arrow that you drew to center of your shadow.
5. Sun Compass now points to the four directions.

**Sun Compass™** is available for the following latitudes:

1. U.S.A. (25° to 55°) – shown here
2. Northern (50° N to 70° N)
3. Equatorial (20° N to 20° S)
4. Southern (10° S to 40° S)





77

## 4.5 Setting the Solar Array Tilt Angle

Maximum performance is obtained from a solar pump when its photovoltaic array is tilted (elevated) to face the sun. The solar array racks that are supplied with *ETAPUMP Integrated Systems* are adjustable to the desired tilt angle. It is the responsibility of the installer to perform this adjustment.

Some *ETAPUMP Integrated Systems* include a solar tracker, and others with a fixed (non-tracking) rack. Both types of array have a manual tilt-angle adjustment. (The tracker follows the daily path of the sun, but not the seasonal tilt variation.)

The optimum tilt angle is determined by the location (latitude). It also varies with the time of the year. This data is presented in the table below.

Should the tilt angle be adjusted periodically through the year? This depends on the seasonal water-use pattern, and also on human factors. There are three options to chose from.

**Select one of these options for seasonal management:**

1. **Year-round compromise** (no seasonal adjustment) Set the angle equal to the latitude of the location and "forget it". This is practical because people often forget to adjust the array. The performance displayed in the ETAPUMP System Sizing Table is based on this fixed compromise setting of the tilt-angle.
2. **Seasonally adjusted** It is sufficient to perform the adjustment only twice per year, at the spring and autumn equinoxes, to the summer and winter angles indicated below. For central USA, this will increase the daily water production by about 8% in summer, 5% in winter compared to option 1.
3. **Seasonal use only** If the pump is to be used no more than half of the year, set the array to the appropriate seasonal angle shown below, and "forget it".

**CAUTION People often forget to make seasonal adjustments.** If you use the pump all year but do not want seasonal adjustment to be required, set the angle to *year-round compromise* (equal to latitude).

**Ideal angles (from horizontal) are:** Summer optimum = latitude - 15° Winter optimum = latitude + 15°

### Solar Array Tilt Angles by Latitude

| Location (examples) | Latitude | Summer Tilt | Winter Tilt | Year-Round Compromise |
|---|---|---|---|---|
| Southern Canada | 50° | 35° | 65° | 50° |
| Upper Third of USA | 45° | 30° | 60° | 45° |
| Middle Third of USA | 40° | 25° | 55° | 40° |
| Lower Third of USA | 35° | 20° | 50° | 35° |
| Central Mexico | 20° | 5° • | 35° | 20° |

• 0-25° latitudes Apply a minimum tilt angle of 10°, or dust and debris will accumulate.



78

# 5 ELECTRICAL INSTALLATION

## 5.1 Controller, Junction Box, and Conduit

**WARNING To be installed, connected and serviced by qualified personnel only. Ensure all power sources are disconnected when making connections to the controller. Follow all appropriate electrical codes. There are no user serviceable parts inside the motor or the controller.**

**System Wiring Diagram** If your pump was purchased as part of an *ETAPUMP INTEGRATED SYSTEM™*, a System Wiring Diagram should be attached at the back of this manual.

**Location** Place the controller close to the solar array, not the pump. This will reduce the risk of lightning damage. *Explanation — The controller's input circuitry is more sensitive to surges than its output. It is safest to minimize the length of the input wiring.*

**Protection from solar heat** Electronic devices are most reliable when they are protected from heat. Mount the controller in the shade of the mid-day sun. An ideal location is directly under the solar array, on the north side of the mounting pole. If shade is not available, cut a piece of sheet metal and bolt it behind the top of the controller. Bend it over the controller to provide shade. This is especially important in extremely hot locations. Extreme heat may trigger a thermal switch in the controller and cause it to turn off.

**Location of controller** Mount the controller vertically to keep out rainwater. It is preferable to mount it ON THE NORTH SIDE of a pole or other structure, to help reduce solar heating. This may also allow easiest access without hitting your head on the lower (south) edge of the array.

**Junction Box**
A pre-wired junction box is included with your system. The junction box terminals will handle pump wires as large as #6 (13 sq. mm). If large wires cannot be accommodated easily in the box, you can join them to smaller wires in the junction box. #12 (4 sq. mm) or larger is acceptable for this very short length. Do NOT remove terminal screws. If the key to the junction box gets lost, it can be opened with a screwdriver.

**Mounting the controller and junction box to a pole** See photos on the following page. The controller can be mounted onto the solar array support pole using materials available from your local electric supply store. The best mounting hardware is "slotted strut" (*Unistrut®* or equivalent) with matching conduit clamps to fit around the mounting pole. This makes a very strong assembly that is easy to adjust. In North America, these materials are commonly available from electric suppliers.

Other methods of mounting to a pole:
1. Make "U-bolts" from threaded steel rod. You may need to drill additional holes in the junction box. Seal unused holes with a permanent sealant.
2. Attach a metal plate to the pole and bolt the boxes to the plate.
3. Drill and tap holes in the pole, drill matching holes (centered) in the boxes, and bolt them directly to the pole.

**Electrical conduit is recommended** We urge you to use electrical conduit (pipe) to protect outdoor wiring from the weather, from human activities, and from chewing animals. See photos on the following pages. If you don't use conduit, use strong, high-quality outdoor cable. Where cables enter the junction box, install sealed strain-relief cable clamps.

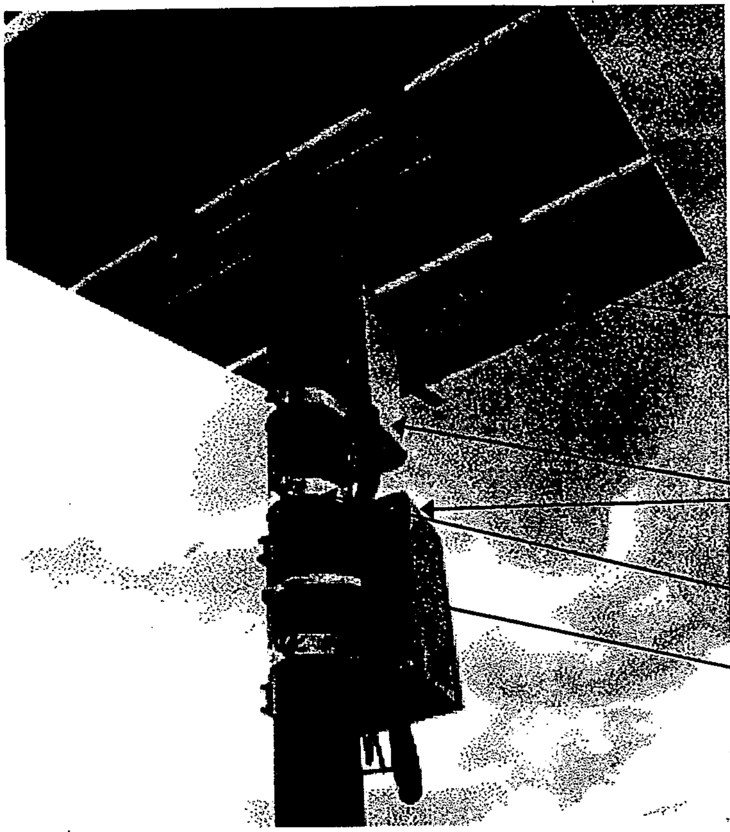
**Keep the controller and junction box sealed** Unused holes must be sealed to keep out animals, insects, water and dirt. Each hole is supplied with a rubber plug that can be kept in place for this purpose.

**Battery system** Batteries must be in a cool location for best longevity, and in a protective enclosure for cleanliness and safety. Place the controller near the batteries but NOT in the same enclosure. They must be safely isolated from the battery terminals and from corrosive gasses.

**CAUTION Loose connections are the most common cause of system failures.**
Pull on each connection to confirm that it is secure.



79



Typical assembly of the controller and junction box on the solar array mounting pole. Boxes are secured using slotted strut and conduit clamps.

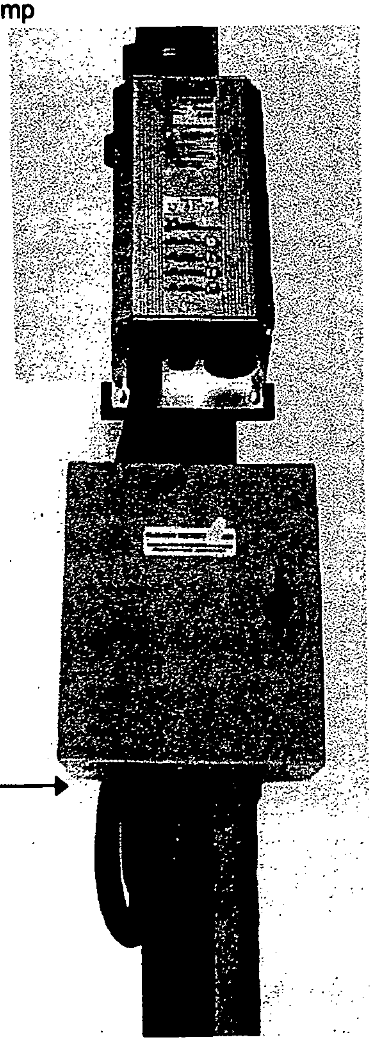
Mount the controller on the north side of the pole to reduce solar heating.

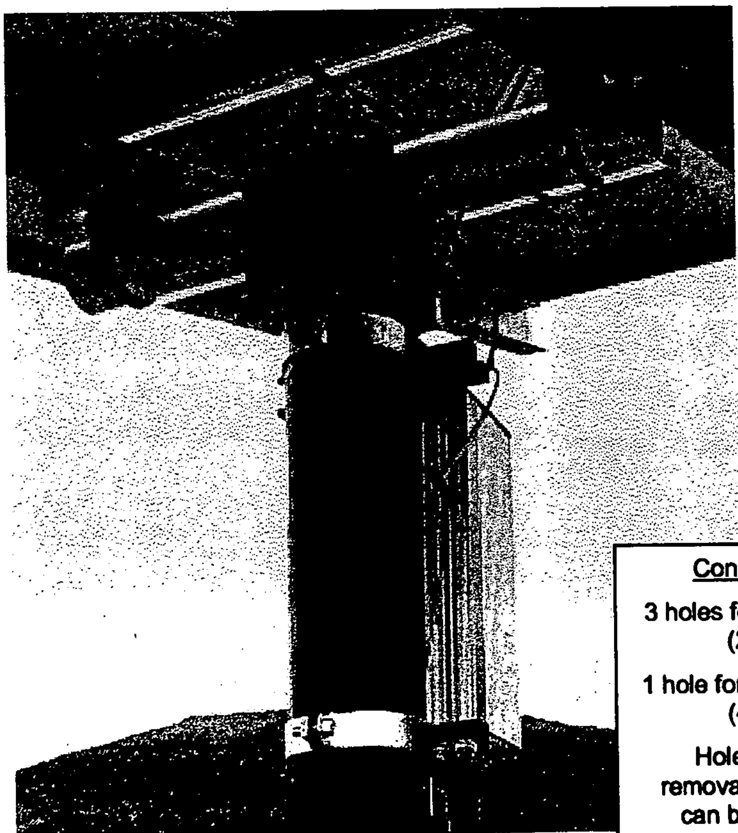
Bare ground wires bond the PV modules to the controller enclosure, and continue down to the ground rod. Flat braid is flexible and eliminates the need for terminal lugs.

slotted strut (*Unistrut®* or equivalent), cut to the width of the box.

conduit clamp to fit slotted strut

hose clamp





<u>Conduit holes</u>

3 holes for 3/4" conduit (28mm)

1 hole for 1 1/4" conduit (45mm)

Holes are in a removable plate that can be reversed.



80

## 5.2 Grounding and Lightning Protection

**WARNING Failure to install and connect an effective grounding system will greatly increase the risk of lightning damage and will void your warranty.** We suggest you wire the grounding system FIRST so it is not overlooked. The concrete footer of a ground-mounted array will NOT provide adequate electrical grounding.

Surges induced by lightning are one of the most common causes of electronic controller failures in solar water pumps. Damaging surges can be induced from lightning that strikes a long distance from the system, or even between clouds. The risk of damage is greatly reduced if these instructions are followed.

**Construct a discharge path to ground** A properly made discharge path to ground (earth) will discharge static electricity that accumulates in the above-ground structure. This helps prevent the attraction of lightning. If a lightning strike occurs at close proximity, a well-grounded conductive structure can divert the surge AROUND the power circuitry, greatly reducing the potential for damage. The *ETAPUMP* controller has built-in surge protectors, but they help ONLY if the system is effectively grounded.

**Earth connection – Create an effective discharge path** It helps to picture this as a "drain field" for electrons. Here are suggestions for grounding, in order of their efficacy:

1. The best possible ground rod is a steel well casing located near the array. Drill and tap a hole to make a strong bolted connection to the casing with good metallic contact. Bolt on a brass terminal lug. After the connection is made, seal the connection with silicone sealant or other waterproof compound to prevent corrosion. Protect the ground wire(s) from physical damage so they aren't stressed by being stepped on, etc.
2. Install a copper plate or other specialized grounding devices designed for the purpose. Some systems use salts to improve the conductivity of the surrounding soil.
3. Install one or more copper-plated ground rods at least 8 feet (2.5m) long, preferably in moist earth. Where the ground gets very dry (poorly conductive), install more than one rod, spaced at least 10 feet (3m) apart.
4. If the soil is rocky and doesn't allow ground rods to be driven, bury BARE copper wire in a trench at least 100 feet (30m) long. If a trench is to be dug for burial of water pipes, ground wire can be run along the bottom of the trench. The wire size must be minimum #6 (16 sq. mm) or double #8 (10 sq. mm). Connect one end to the array structure and controller. Or, cut the ground wire shorter and spread it in more than one direction.

To achieve good grounding in a dry, rocky location, consult a local contractor who specializes in lightning protection. It is best to plan the procedure in advance, and to coordinate the effort with other earth-excavating procedures that need to be done. Reference: www.lightning.org

**Bond (interconnect) all the metal structural components and electrical enclosures** Interconnect the PV module (solar panel) frames, the mounting rack, and the ground terminals of the disconnect switch and the controller, using wire of minimum size #8 (6mm2), and run the wire to an earth connection.

**Ground connections at the controller** The controller and junction box have redundant ground terminals inside. They are all connected in common with the metal enclosures of both the controller and the junction box. Ground connections can be made to any of these points.

**Ground connections to aluminum** This applies to connections at the solar array framework, and at the controller's enclosure box. Connections to aluminum must be made using terminal lugs that have an aluminum-to-copper rating (labeled "AL/CU") and stainless steel fasteners. This will reduce the potential for corrosion.

**DO NOT GROUND the positive or the negative of the power circuit.** The best lightning protection results from grounding the metallic structure only, and leaving the power system ungrounded. This is called a "floating" system.
***Explanation:*** *With a floating system and a good structural ground, lightning induced surges tend to reach ground through the structure, instead of the power circuit. When high voltage is induced in the power circuit, the voltage in negative and the positive sides tend to be nearly equal, thus the voltage BETWEEN the two is not so high, and not usually destructive. This method has been favored for many decades by most engineers in the remote power and telecommunications fields.*
***Exception for battery systems:*** You can connect the pump to a battery-based home power system that has a negative ground. If the wiring distance to the pump exceeds 100 feet (particularly in a high lightning area), DC-rated surge protection devices are recommended.
***Legal exception:*** If the local electrical authority requires power circuit grounding, ground the PV ARRAY NEGATIVE wire. This may increase the risk of lightning damage.



81

**Solar array wiring** Bind the array wires close together, or use multi-wire cable. Avoid forming loops. This helps induced voltages in each side of the circuit to equalize and cancel each other out.

**Wire twisting for long runs** Twisting wires together tends to equalize the surge-induced voltage so the voltage differential between the wires is small. This reduces the probability of damage. This method is employed in telephone cable, for example. Some power cables are manufactured with twisted conductors. To twist wires yourself, you can alternate the direction of the twist about every 30 feet (10 m). This makes the job much easier.

**Float switch cable** A long run of control cable to a float switch can pick up damaging surges from nearby lightning. The best protection is to use shielded, twisted-pair cable (Dankoff Solar Item #10326). Shielded cable has a metallic foil or braid surrounding the two wires. Ground the cable shield as illustrated in Section 5.10.
**CAUTION Ground the cable shield at the controller end only, not at the float switch.**

**Additional lightning protection** The *ETAPUMP* controller has built-in surge protection devices. However, additional grounding measures or surge protection devices are recommended under any of the following conditions:

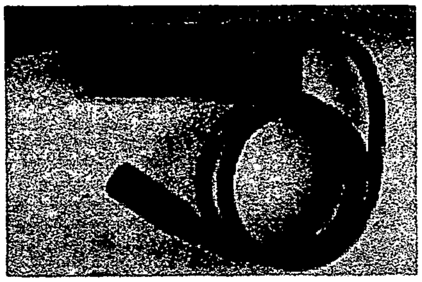
1. Isolated location on high ground in a severe lightning area
2. Dry, rocky, or otherwise poorly conductive soil
3. Long wire run (more than 100 feet / 30m) from the controller to the wellhead, or to the float switch.

Additional lightning protection devices (surge arrestors) can be obtained from your *ETAPUMP* supplier. The device(s) for the controller's PV input, float switch and probe connections, must be rated for DC. The device(s) for the controller's AC output to the motor must be rated for 3-phase AC. In each case, the clamping (bypass) voltage should be 90V or higher, but not much higher.

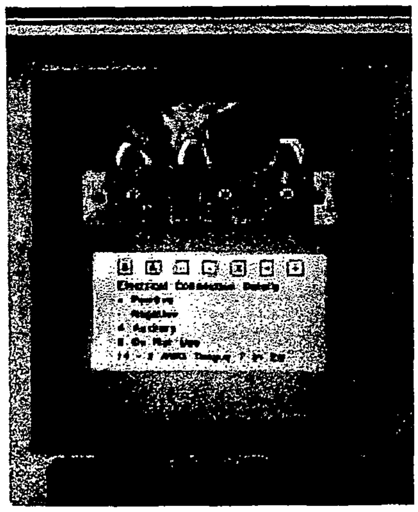
**WARNING Isolate solar pump wiring from electric fence systems.** Do not connect the pump system to the same ground rod as an electric fence. Do not run power or float switch cables close to an electric fence.

## 5.3 Solar Array Wiring

**WARNING: The photovoltaic array generates hazardous voltages. A 48 Volt (nominal) array can generate nearly 100 volts when disconnected from load. A short circuit or loose connection will produce an arc that can cause serious burns. All wiring must be done by qualified personnel, in compliance with local, state, and national electrical codes.**



The solar array can produce hazardous voltage even under low light exposure. To prevent shock hazard while wiring the array, leave one or more wires disconnected or cover it with opaque material.



*ETAPUMP* solar-direct (non-battery) systems use a variety of array configurations. Some use 12V (nominal) modules, and some use 24V modules. Modules are connected in series for 36 or 48V, and sometimes also in parallel to increase the current. **Refer to the System Wiring Diagram** for your system, attached at the end of this manual. Be sure the modules (panels) match the description on your System Wiring Diagram.

**Solar module connections** The terminals in the module junction boxes can be confusing. Refer to the module manufacturer's instructions that are packed with the modules. Make strong connections that will hold for many years. Most array failures are caused by loose, corroded, or shorted connections.

**PHOTOS** show two types of PV module junction systems.
**TOP** Quick-connect system using "MC" connectors.
**BOTTOM** Junction box with screw terminals and conduit holes.

**Type of wire** Use either electrical conduit or outdoor UV-resistant wire. The solar array has a life expectancy beyond twenty years. Don't degrade it with inferior materials! Use minimum wire size #12 (4 sq. mm) for the connections between modules and for short distances to the controller. Some appropriate types of wire are: USE, UF, SE and SOOW.



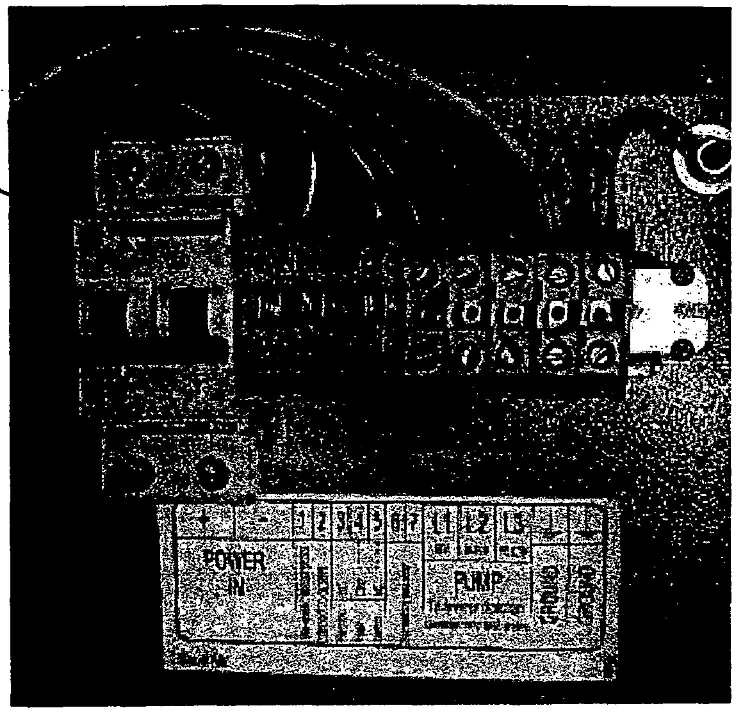
82

**Solar tracker wiring** If you are installing a solar tracker, pay careful attention to the wire section that leads from the moving rack down to the stationary mounting pipe. Use a highly flexible wiring assembly. Form a drip loop to shed water and to minimize stress. SEE TRACKER PHOTO and caption in the PHOTO GALLERY. Secure the assembly mechanically at each end so the insulation and the connections are not stressed by the tracker's motion. Swing the tracker fully in each direction, at various seasonal tilt angles, to verify that the cable will not rub or restrict the tracking motion.

**MC connectors** Some PV modules have these quick connectors. If the connector is not appropriate at some junctions, you can cut the wire and make a conventional connection.

## 5.4 Solar Array Disconnect Switch in the Junction Box

**PHOTO** Inside of junction box showing the factory-installed wires that lead to the controller.




**DISCONNECT SWITCH**

The disconnect switch satisfies National Electrical Code requirements for a safety disconnect between the solar array and the controller. During installation and maintenance, switch off the disconnect switch to prevent shock and arc burn hazard.

Note: Overload protection (fuses or circuit breaker) is NOT required in the solar array circuit. *Explanation:*

1. *Short circuit current from the solar array can never reach the ampacity (maximum safe amps capacity) of the recommended wire.*
2. *The ETAPUMP controller has internal overload protection.*

**CAUTION Loose connections are a common cause of failure. Pull each connection to confirm.**

## 5.5 Junction Box (Controller Input) Wiring

**System Diagram** For solar-direct systems, refer to the System Diagram at the end of this manual.

**WARNING TEST THE VOLTAGE before connecting power to the controller. Voltage (open circuit) must not exceed 90V. (Even in cloudy weather, the open circuit voltage will be near maximum.)**

**WARNING Do not apply a direct connection or an amp meter between + and – when the controller is connected. A short circuit here will cause a strong discharge.**

**WARNING SOLAR-DIRECT systems only — Do not connect any electrical load to the solar array if it is not part of the *ETAPUMP* system.** Connection of a battery charger, active solar tracker controller, electric fence charger, or other load simultaneously with *ETAPUMP* will "confuse" the controller and prevent proper operation.

**Ground connections** The two ground terminals in the junction box are bonded together and are also bonded to the metallic enclosures of both the junction box and the controller. See Section 5.2



83

**POWER IN** Ensure that the solar array DISCONNECT SWITCH (or battery fuse or circuit breaker) is OFF. Connect the power from the solar array to the input terminals in the junction box. Observe polarity. If your wires are not clearly marked +/–, test them using a DC voltmeter or multitester.

**PUMP** See Section 5.8.

**Low Water Probe** See Section 5.9
**If you are not using a low-water probe** connect a small wire between terminals 1 and 2.

**Float Switch** See Section 5.10, Automatic Control for Full-Tank Shutoff. A connection is made at the factory between terminals 4 and 5. If you are NOT using a float switch, leave this connection in place.

## 5.6 Maximum RPM Setting (EP-600 controllers only)

All solar-direct systems and some battery systems use the EP-600-series controller. This controller offers the option of reducing the maximum speed of the pump. (This does NOT apply to battery systems with ME-series controller.)

This RPM control reduces the maximum speed (RPM limit) to as low as about 50%. It will NOT reduce the starting or low-light performance. The pump uses less power when it pumps less water.

**Reasons to reduce the maximum RPM**
1. To prevent over-pumping a limited water source (see Section 6.7)
2. To improve energy and water-source management in a battery system where slow pumping is adequate to meet the demand
3. To limit the back-pressure (and prevent possible pump overload) when pumping into a direct-pumped irrigation system, a filtration system, or an undersized pipeline
4. ***ETAPUMP* Model ETA-75C** Set the control mid-way between positions 1 and 2
5. ***ETAPUMP* Model ETA-107C** Set the control to position 2

**WARNING For model ETA-75C, ETA-107C, failure to perform this adjustment will void the warranty.**

**How to reset the Maximum RPM setting**
1. Remove the bottom end of the EP-600A controller enclosure (the end with the conduit openings)
2. Locate the adjustment knob shown in the photo below (circled)
3. In most cases, the knob will be at the standard factory setting full clockwise. Turn it counter-clockwise to the ink mark illustrated as #2 in the illustration below. The exact position may vary from this illustration.

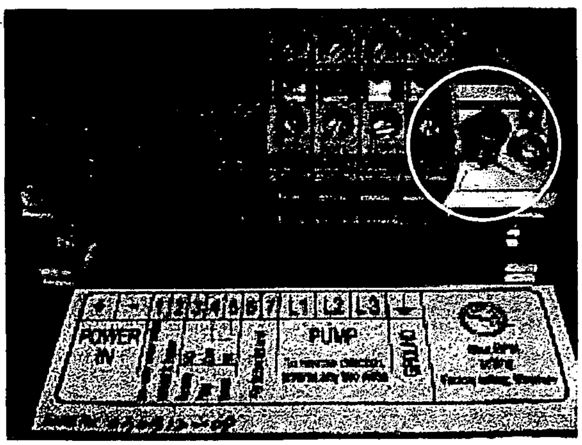
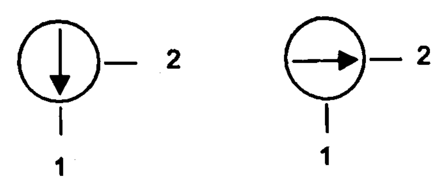



**PHOTO** Terminals inside the EP-600A controller. "Max. RPM setting" is at right. The two ink marks correspond to positions 1 and 2 illustrated below.

**← Maximum RPM setting knob**

| **ORIGINAL FACTORY SETTING #1** | **REDUCED POSITION #2** |
| --- | --- |




**If you perform this adjustment, write the setting here →** ______ **Date** ______ **by** ______



84

## 5.7 Submersible Pump Cable and Splice

**Selection of cable** Use only an approved type of submersible well pump cable, the same type that is used for conventional AC pumps. It is available from your *ETAPUMP* supplier or installer, or a local water well supply distributor. You need 4-conductor cable. It is often called "3-wire-with-ground" because it has 3 power wires plus a ground wire. To determine the minimum required wire size, refer to the *ETAPUMP* Systems Sizing Table.

**Submersible Splice** A splice kit is included with *ETAPUMP Integrated System™*. It includes crimp connectors to join the copper wires, adhesive heat-shrink tubing, and instructions. If the drop cable is too large to fit in the crimp connector, cut off some of the wire strands. Use a crimping tool, and observe that the wires are held very securely.


PHOTO – Submersible cable splice, before protective tape is applied

When the heat-shrink tubing is heated, it shrinks and the adhesive melts and bonds to the wires. Each wire must be sealed 100% water-tight. After this is complete, wrap tape around the entire splice, to give mechanical protection. It is NOT necessary to provide a water-tight seal around the outer jacket of the cable. If you make a mistake or lose your *ETAPUMP* splice kit, you can obtain a submersible splice kit from any well pump supplier.

## 5.8 Wiring Order for Correct Rotation

**WARNING If the pump wires are in the wrong order, the motor will run in reverse and the pump will not function. Damage may result. Check the direction BEFORE installing the pump. The proper direction is COUNTER-CLOCKWISE when viewed from above.**

**WARNING When testing for direction, do not run the pump dry for more than 15 seconds.**

The power wires on the pump are black with white lettering to indicate L1, L2 and L3. WRITE DOWN the colors that you splice to L1/ L2 / L3 so you can match them with the L1/ L2 / L3 terminals in the pump controller.

**If your pump cable has the standard RED, BLACK and YELLOW colors, use this sequence:**

| RED | BLACK | YELLOW | GREEN |
|---|---|---|---|
| L1 | L2 | L3 | Ground |

**Testing the pump for direction** Helical rotor pumps will produce water flow only if they are rotating in the right direction. If you place it in a water tank or a bucket, you will observe flow if the rotation is correct. (Submerge at least 75% to observe full flow).

**Alternative, dry test** If you don't have a water vessel to test the pump in, you can test it dry by watching the pump shaft and running it for only a few seconds. The metal label on the pump has an arrow to indicate the proper direction of rotation. If the pump is new from the factory, it is lubricated so it can run dry for about 90 seconds without risk. If the pump is not new, it can be run dry safely for about 15 seconds. Either way, this is more than enough time to observe the direction of the shaft.

If you did not write down the color match (or the wind blew your note away) connect the three power wires to the controller in ANY random order. Apply power. Observe the pump shaft rotation, then turn the power off. If the direction is wrong, exchange ANY TWO of the power wires at the controller. In any case, when you are finished connecting the pump to the controller, test it to assure the proper direction.



85

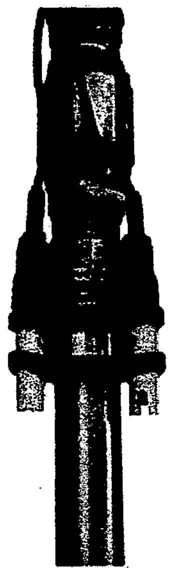
**Did you install the pump in the well without checking the wiring order or the direction?**
**OR – Is it running but not pumping?**

**HELICAL ROTOR pump (model number does NOT contain "C")** Turn the pump on. Observe if air is rising from the pipe. If it isn't, reverse any two motor wires and observe again. If you cannot observe air rise, chose whichever direction is quieter (less vibration). There is risk of dry-run damage if it runs too long in reverse. If the pump is new from the factory, it is lubricated so it can run dry for about 90 seconds without risk. If the pump has been used, it must not be run for more than about 15 seconds. In many cases, a pump that is reversed will turn off due to overload.

**CENTRIFUGAL pump (model number contains "C")** In reverse, it will produce no flow (or very little). This will NOT damage the pump. If the flow is not normal, reverse any two motor wires.

**Question** *The motor shaft is hard to turn by hand, and moves in a bumpy manner. Is this normal?*
***Answer*** YES. This is caused by permanent magnets in the motor. It is especially hard to turn when it is connected to the controller, or if the pump wires are connected together.

## 5.9 Low-Water Probe for Dry-Run Protection



**WARNING Running completely dry will damage the pump end and void the warranty.**

The purpose of the probe system is to sense the loss of water and turn the pump off. The normal position for the probe is just below the pump's check valve, as shown in the photo.

**Probe wires** The probe circuit requires submersible wires of #16 AWG. Larger wire can be used, but it is not necessary. #16 submersible wire is available in single-conductor form, so two wires are required. The American designation is "type TFF". This can be ordered from your supplier (Dankoff Solar item #11421). Order 2X the length from controller to pump.

**Probe wire connection** Splice the wires to the short wires on the probe using the splice kit included with the pump. These use heat-shrink tubing, like your main pump splice (see splice kit instructions). In the controller, connect the well probe wires to the well probe terminals.

**Operation** The probe senses electrical conductivity through the water, between two electrodes. If the water level drops below the probe, continuity is lost. The controller will stop the pump and the "Low-Water OFF" light will indicate. When the water level recovers and again contacts the electrodes, the controller will delay the restart for 20 minutes. To force a restart, turn the controller off, then on again.

**The Low Water-OFF light stays ON for the remainder of the day,** even if the water recovers and the pump restarts automatically. This tells you that the water source ran low at least once since the power was disrupted (or sun went down). To turn the light off, reset the controller by turning it off/on.

**If you are not using the well probe,** connect a short wire between the probe terminals in the junction box (terminals 1 and 2). Do this only if you feel certain about the reliability of the water source.

**CAUTION Do not use a pressure switch with a "low water cutout" or "loss of prime" feature as a method of dry-run protection.** A helical rotor *ETAPUMP* will maintain pressure as it runs dry. The "dry" cutout feature will not work reliably. For pressure switch information, see Section 5.12.

**Potential problems with the low-water probe** *ETAPUMP* uses shielded probes with very low voltage and current, to minimize potential problems. However, there are some extreme conditions to be aware of. A thick accumulation of minerals, bacteria or algae may cause failure of the low-water probe to detect a low-water condition, due to excessive conductivity between the electrodes. Possible solutions are:
1. Hang the probe independently of the pump and pipe (not clamped). This way, it can be pulled up for testing, inspection or service without the need to pull the pump. Also, its position can be adjusted if desired. This may be difficult or impossible if the well casing is smaller than 6". (See Section 6.3 Safety Rope and Binding.)
2. Pull the probe out periodically (with the pump if necessary) for testing and inspection. The pump should stop at the moment the probe leaves the water.

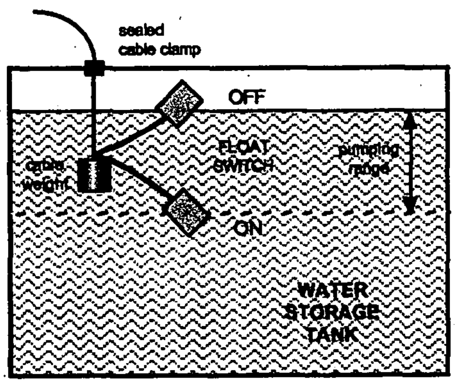


86

3. If you have a low-production water source, consider reducing the max. pumping rate — see Section 6.7 Utilizing a Low-Production Water Source. This will reduce the dependency on the probe system.
4. Substitute a mechanical float switch, if there is sufficient space in the water source. It must make contact when the water rises.

**Erosion of the probe** Erosion is a loss of electrode material by electrochemical action. This is NOT likely to occur during the lifetime of the pump, but it may happen in some extreme water conditions. The low-water shutoff will continue to function until an electrode has practically disappeared, then it will stop the pump. The electrodes use DC power, so only one electrode will erode. If you see significant erosion of one electrode, reverse the polarity of the probe connections. This will cause the "good" electrode to erode instead.

## 5.10 Automatic Control For Full-Tank Shutoff




We recommend the use of a float switch or other means to prevent overflow of your tank. This will stop the pump when the tank is full, then reset when the level drops. This conserves ground water, prevents overflow, and eliminates unnecessary pump wear. *ETAPUMP* controllers allow the use of small signal cable to a remote float switch, even if the tank is a long distance away.

**Float switch requirements**
1. A switch must be used, not wet electrodes.
2. It must not be allowed to switch on/off rapidly.
3. The preferred system requires a float switch to MAKE contact on rise to turn the pump OFF. This is called "normally open" (N.O.). It may be commercially labeled as a "pump down" switch, but here it works in reverse, to allow pumping up.

*Float Switch Kit* from Dankoff Solar (Item # 10320) meets these requirements. Obtain it from your *ETAPUMP* supplier. The kit includes a sealed float switch (non-mercury type), cable weight and cable clamp as illustrated.

**Float switch cable requirements**
1. Two wires are needed.
2. Minimum wire size #18 AWG. This is good for a distance as far as 2000 feet (600 m).
3. The cable must be suitable for its environment.
4. If it must run a long distance, use twisted-pair shielded cable to reduce the chance of damage from lightning-induced surge. (See Section 5.2 Grounding and Lightning Protection).

*Float Switch Cable* (Dankoff Solar item #10326) meets these requirements. It is approved for sun exposure and direct burial, with twisted-pair wires and a metallic shield for surge resistance.

**Wiring to the junction box** The controller (and junction box) offers two options for connection of a remote switch. These allow the use of either a "normally open" (N.O.) or a "normally closed" (N.C.) switch. "Normal" refers to the status of the contacts when the switch is DOWN and calling for water.

**Wiring the *Dankoff Solar Float Switch Kit* (Item #10320) or other "normally open switch"** Connect the switch to terminals 3 and 4 (NO and common) and connect terminals 4 and 5 together, as illustrated.

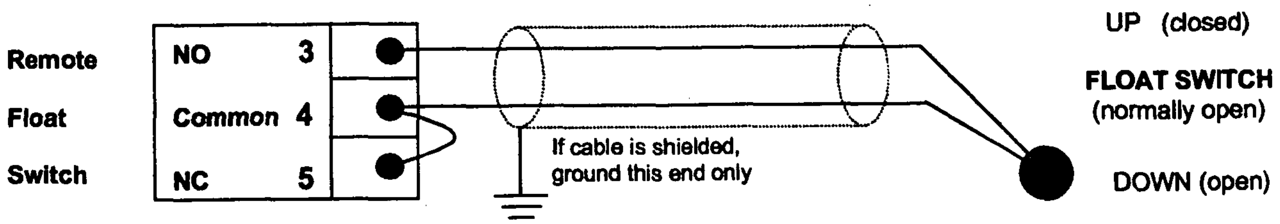



**ILLUSTRATION Connection of *Dankoff Solar Float Switch Kit*** (normally open) to junction box terminals
Closing (connecting) the switch circuit turns the pump OFF



87

*QUESTION Why do we use a reverse-action (N.O.) float switch? (a pump-down switch for a pump-up application)*
*ANSWER If the cable connection is broken, the pump will continue to operate. The water supply will not be disrupted (but of course, the tank will overflow). This is the general preference in the industry. If you prefer the pump to stop if the connection is broken, use a normally closed (N.C.) float switch instead.*

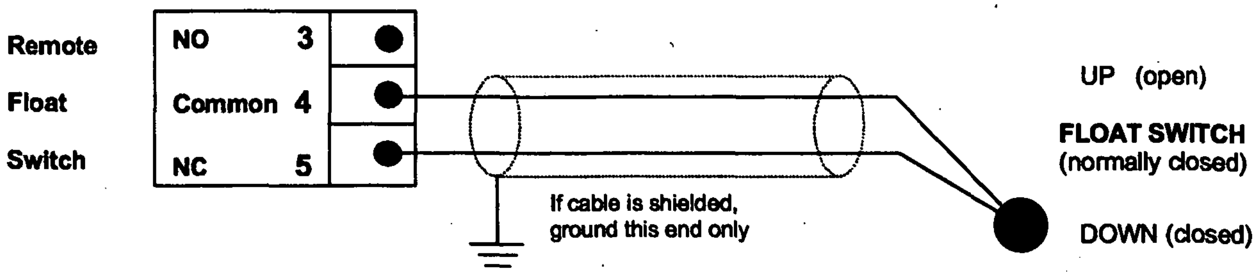



**ILLUSTRATION** Connection of NORMALLY CLOSED float to junction box terminals
This is also called a "pump up" switch.
Opening (disconnecting) the switch circuit turns the pump OFF.
This connection can also be used for a manual remote switch.

**Grounding shielded float switch cable** If you use shielded cable (containing a metallic foil or braid around the wires, like Dankoff Solar *Float Switch Cable*), connect the shield to ground AT THE CONTROLLER ONLY. Do NOT ground the shield at the float switch. This will reduce surges induced by nearby lightning.

**If you are not using a float switch,** terminals 4 and 5 must be connected. Terminal 3 remains disconnected.

**Operation of the float switch system** When the water level is high, the float switch will stop the pump. The FULL-TANK OFF indicator on the controller will light up. When the water level drops, the float switch will signal the controller. The indicator light will go out, and the pump will restart if sufficient power is available.

**Overriding the float switch** You may want to override the float switch to allow overflow for irrigation purposes or to test or observe your system. For a N.O. switch circuit, install a switch to DISCONNECT ONE of the float switch wires. FOR A N.C. switch circuit, install a switch to CONNECT the two float switch wires together.

**A conventional pressure switch and float valve for wireless level control** It may be feasible to use a float valve in the water tank to cause back-pressure when the tank is full, and to trigger a conventional pressure switch. Wire the system as you would for a pressurizing system. Observe these precautions:

1. The *ETAPUMP* system must be capable of producing at least 25 PSI more than the full lift pressure. (A conventional pressure switch will not work reliably at lower pressures.)
2. Float valves often leak. Be sure the tank can overflow safely.
3. Adjustment of the switch is delicate. Be sure to observe it carefully to verify the action.
4. Rapid start/stop cycling will "confuse" the controller. To prevent rapid cycling, install a small pressure tank near the pressure switch. A tank of 2 gallons (8 ltr) or larger is sufficient.
5. Precharge the pressure tank to a pressure that is slightly less than the cut-in pressure.
6. Install a pressure relief valve (see Section 5.12).

**MANUAL REMOTE CONTROL SWITCH** The float switch circuit can be used with a manual switch to turn the pump on and off from a distance. Use any general-purpose on/off switch available from an electronic supply, electrical supply, or hardware store (it only carries 12 volts, very low current). Wire it according to the illustration above, for a normally closed float switch.



88

# 5.11 Battery-Based Systems

***ETAPUMP* using a storage battery system must use controller Model EP600AB or ME-series.** DO NOT run these controllers directly from a solar array without batteries, or damage will result. **24 volt systems** must use an ME controller.

**Overload protection** *ETAPUMP* controllers have built-in electronic overload protection, but a fuse or circuit breaker must be installed near the battery (usually in the distribution box) to prevent fire hazard in case of a short circuit. Use a 25 amp circuit breaker or a time-delay (slow blow) fuse – same for 24 or 48V.

**Wire Sizing for the DC circuit** Wire must be sized for no more than 5% voltage drop at 20 amps (starting). Refer to a wire sizing chart specifically for 24V or 48V, or follow these examples:

| | |
|---|---|
| 24V SYSTEM: #10 wire to maximum distance of 30 ft. | Metric: 6 sq. mm to max. 10m |
| 48V SYSTEM: #12 wire to maximum distance of 22 ft. | Metric: 4 sq. mm to max. 13m |

GREATER LENGTHS: For each 150% increase, use next larger wire size.

**Low-voltage disconnect function.** Lead-acid batteries can be permanently damaged by over-discharge when the voltage falls below a critical point. To prevent this, the *ETAPUMP* battery-system controller will turn off at low voltage, and turn back on only after the battery has recovered significantly. The set points are:

| | | |
|---|---|---|
| 24V SYSTEM: | OFF at 22V | ON at 26V |
| 48V SYSTEM: | OFF at 44V | ON at 52V |

A controller in disconnect mode can be reset manually by turning off/on, but it will quickly turn off again if the battery is not gaining a substantial recharge.

**CAUTION The *ETAPUMP* controller is NOT a battery charge controller.** A charge controller prevents battery overcharge. It is a normal part of any renewable energy battery charging system. Be sure the charge controller is appropriate to the type of batteries used. (Sealed batteries use lower voltage settings than liquid-filled batteries.)

# 5.12 Pressurizing Systems

*ETAPUMP* is excellent for automatic water pressurizing when powered by a battery system. If you are raising water vertically AND pressurizing, the pump must handle to total head. Note the relationship: 2.31 ft. = 1 PSI (1 Bar = 10 vertical meters.) Example: A pump that lifts 100 vertical feet (30m) and pressurizes to 60 PSI (4 bar) must pump the equivalent of 240 feet (70m). Be sure your pump was chosen correctly for your application. The installation is similar to that of a conventional AC pump.

A typical pressurizing control assembly is illustrated in the following photo. These are standard components, same as used for conventional AC water pressure systems. The parts (from left to right) are:

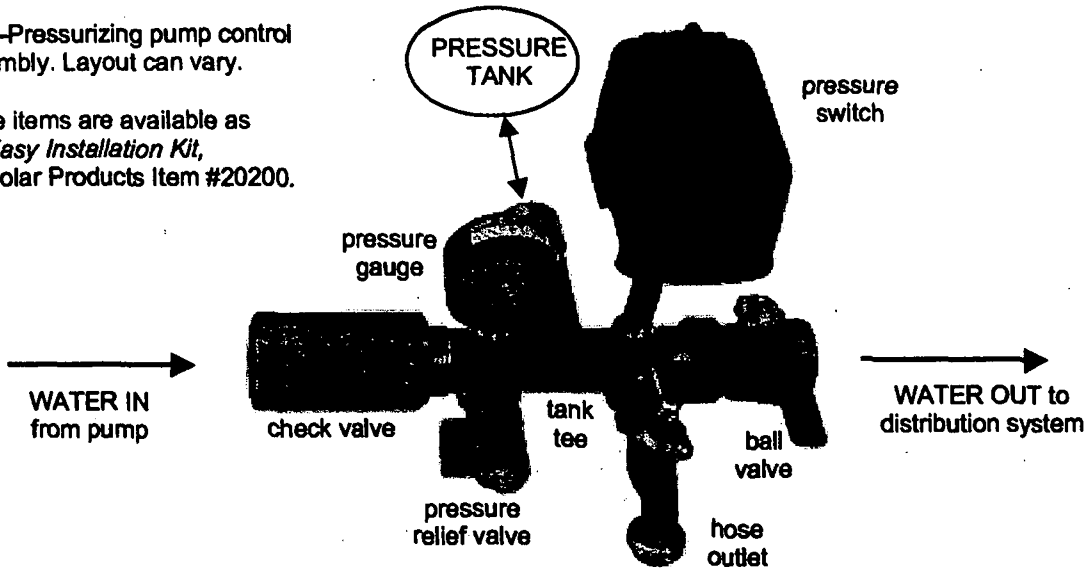
1. check valve (prevents back-flow)
2. pressure gauge 0-100 PSI (0-7 bar)
3. pressure relief valve 75 PSI (5.3 bar)
4. tank tee a bronze casting that holds all the components
5. pressure switch turns the pump on/off according to pressure set-points, adjustable
6. hose outlet to drain the system or to supply water when outlet is shut off
7. ball valve to shut off the supply to the outlets

The components can be purchased from local suppliers, or as a kit. (The photo shows Dankoff Solar "Easy Installation Kit" Item #20200. All parts are brass except the pressure switch.)

**WARNING A PRESSURE RELIEF VALVE IS REQUIRED. If the pressure switch fails, this will prevent extreme pressure from bursting the tank or piping and causing a flood.**
**Pressure relief valve** Install the valve near the pressure tank, before the shutoff valve. Use a 1/2" (or larger) valve that is set in the range of 25-75% higher than the cut-out pressure. Run a pipe or hose from its outlet to a drain or to the outdoors where water can drain away without causing damage.

**PHOTO**—Pressurizing pump control assembly. Layout can vary.

These items are available as *Easy Installation Kit,* Dankoff Solar Products Item #20200.




**Pressure tank** A pressure tank is required. We recommend a captive-air pressure tank of 40 GALLONS (150 liters) OR MORE, to assure a steady supply of water pressure as the pump cycles on and off and the water demand varies. A large tank is always best. Size and cost are the only practical limitations. More than one tank can be used to increase the total capacity.

**How to pre-charge a captive-air pressure tank for *ETAPUMP***
For the system to function properly, the air bladder in the tank must be pre-charged with air according to these instructions.

1. Make note of the cut-in setting of the pressure switch (either by observation or knowing the factory setting).
2. Turn off the pump and exhaust the water from the tank if necessary, so the water pressure is 0.
3. Find the air fitting on top of the tank. Measure the air pressure in the tank using a tire gauge.
4. Adjust the pressure to about 3 PSI (.2 bar) LESS THAN THE CUT-IN PRESSURE.
5. IF the system uses CONTROLLER MODEL EP-600, there is a delay in the startup. Compensate by raising the CUT-IN pressure so the pump will start sooner. EXAMPLE: using a 30/50-psi pressure switch, raise the cut-in to 40 psi. There are two adjusting nuts in the pressure switch. To raise the cut-in, turn the SMALLER adjusting nut clockwise about 3 turns, then observe the pressure at which the switch actuates. Readjust if necessary. LEAVE THE TANK PRECHARGE AT THE NORMAL SETTING just below 30 psi.

**Pressure switch** *ETAPUMP* can use an ordinary pressure switch sold for conventional AC pumps. **Do not use a pressure switch with "low water cutout" or "loss of prime" feature** (with a shutoff lever on the side). It is intended to prevent dry run of centrifugal pumps. The helical rotor *ETAPUMP* will maintain pressure even as it runs dry, so this device will not work reliably. It will also shutoff if the pressure falls due to high water demand.

**Pressure switch connection** There are two ways to connect the pressure switch:

1. **primary power switching** The switch is used to disconnect the DC power source. Wire the switch between the power source distribution point and the controller, as you would with a conventional pump.
2. **remote switching** This method uses the " remote float switch" terminals. Small wire (minimum #18 AWG) can be run to the pressure switch from a long distance. See illustration below. *Advantage: the controller stays on all the time. If the water source runs low (even if it recovers) the "Source Low" indicator light will stay on to notify the user. Power draw of the controller is insignificant.*

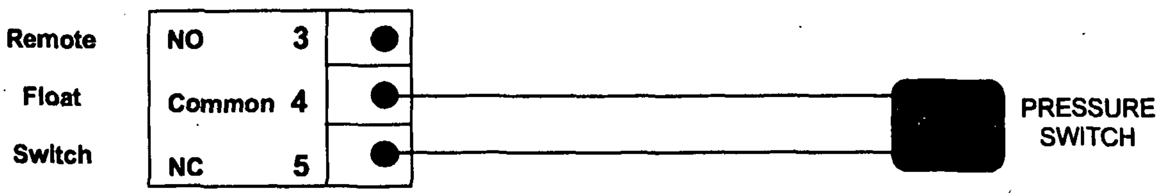



**ILLUSTRATION** Pressure switch connected to the junction box for "remote switching"



90

# 6 PREPARING TO INSTALL THE PUMP

## 6.1 WARNINGS about Handling Helical Rotor Pumps

**WARNING (helical rotor models only) BEFORE INSTALLATION, KEEP THE PUMP OUT OF THE SUN.** If the pump gets hot, the rubber stator will expand and may lock the rotor. No damage will result from this, but you may be unable to test the direction of rotation. If the pump gets hot, allow it to cool in water for 20 minutes before testing.

**WARNING (helical rotor models only) DO NOT APPLY MACHINE GREASE TO THE PUMP. Ordinary machine grease will damage the stator (NBR rubber) and void the warranty.** Helical rotor pumps are lubricated at the factory with a clear, non-toxic grease. Its only purpose is temporary, to allow the pump to be run dry for a short time to test the direction of rotation. There is no normal reason to reapply lubricant but if you do, use *VASELINE* (petroleum jelly, white petrolatum) or non-toxic silicone grease approved for water valves and seals.

**WARNING for SIPHON APPLICATIONS** If a pump system has a vertical lift of less than 33 feet up from the surface of the water source, and then the water flows downhill to a lower point, a siphon effect may cause suction on the pump. This will cause an upward thrust on the motor shaft, resulting in damage to the motor. Prevent this by installing an air vent or a vacuum breaker at the high point on the pipe.

## 6.2 Drop Pipe

**Type of pipe *ETAPUMP* has no special pipe requirements. It can be installed using the same pipe materials as conventional submersible pumps.** *ETAPUMP* produces a smooth flow (no pulsation). It starts slowly, without sudden torque. Thus there is no need for flexible (damping) pipe or a torque arrestor. Use any suitable rigid pipe or flexible pipe with a sufficient pressure rating for the application.

**WARNING Some pumps have a brass check valve. If galvanized steel pipe is to be used, a dielectric (electrically insulated) connection must be made between the galvanized pipe and the pump.** Direct metal-to-metal connection will cause loss of metal to occur at the threaded end of the galvanized pipe, due to electro-chemical action. A short length of plastic pipe, or a plastic fitting, will serve this purpose. A plastic reducer bushing in the check valve is NOT recommended. The metal pipe tends to expand the plastic and crack it.

**Size of pipe** Undersized pipe will reduce the performance of the system. Pipe size is based on the maximum flow rate and the TOTAL length of pipe from the pump to the pipe outlet or tank. Refer to the pump specifications at the end of this manual to determine the peak flow rate for the system you are installing. If a long run of pipe is required, it may need to be larger than the outlet size of the pump. Refer to Section 13.2 Water Pipe Sizing Chart.

**Reduced pipe size should be considered in the following situations:**

1. Sandy water conditions – especially with a solar-direct system. It will pump very slowly on cloudy days. This may cause sediment to accumulate in the drop pipe. Smaller pipe increases the flow velocity and helps exhaust the sediment. (See Section 6.6 "Coping with Dirty Water Conditions".)
2. Hand installation, to reduce the weight, especially for removal when the pipe is filled with water.

Balance these advantages against the increased friction loss in smaller pipe. You can use a pipe size that is smaller than the pump outlet by using a reducer bushing. Do not screw a metal fitting into a plastic bushing. The bushing may crack.

**CAUTION IF POLYETHYLENE (BLACK FLEXIBLE) PIPE IS TO BE USED** See the cautions in Section 7.3.

**WARNING DO NOT USE A ROPE WINCH to install or remove a pump in a drilled well casing (borehole).** If you use a winch to pull the pump by winding up rope or wire rope, the electrical cable can slip down the pipe and/or the pipe can collapse. If the pipe or cable jams and gets wedged in the casing, you can lose your equipment and even permanently block the well! Some installers use a winch with a reel of about 3 feet (1m) diameter or larger, to pull flexible pipe. This is ideal if you have the equipment and experience to do the job safely.

**WARNING DO NOT USE A VEHICLE to install or remove a pump.** During removal, the pump can catch on joints or edges in the well casing. Damage or loss of the pump can occur before the vehicle operator can react.



91

## 6.3 Safety Rope and Binding

**Safety rope** can prevent loss of the pump. If the drop pipe breaks, the rope will prevent strain on the electrical cable and can be used to pull the pump out. Use 1/4" (6mm) water well safety rope. It can be purchased from *ETAPUMP* supplier (Dankoff Solar Item #10360) or from a local pump supplier. Polypropylene marine rope is also good. DO NOT use nylon.


**WARNING Safety rope for well pump installation is for emergency pump removal. It must not be a primary means of support. Make it slightly longer than the drop pipe so it does not bear any weight.**

**WARNING Do not use nylon rope in water.** Nylon absorbs water and weakens after a few years. Failure can cause damage or loss of your equipment. Use polypropylene rope made for water well or marine applications.

**WARNING Plastic rope will weaken from long exposure to sunlight.** Secure it INSIDE the well casing to avoid exposure. If sun exposure cannot be avoided, use stainless steel wire rope.

**Secure the safety rope at the wellhead** Prepare to tie the rope inside the well casing. If your well cap does not have a place to tie the rope, drill a hole in the casing and install an eye-bolt. Prepare this detail BEFORE you install the pump. (See Section 13.3 Wellhead Assembly for Drilled Wells.)

**Bind the drop pipe/cable/wires/rope with tape** Lay out the pipe, submersible cable, probe wires and rope on the ground. Do not twist them together. Bind everything to the pipe about every 10 feet (3-4m) using vinyl tape. Use either standard (UL-listed) electrical tape (about 6 to 8 turns) or "pipe wrap tape", which is wider and requires fewer turns. Pipe wrap tape is available from plumbing and electric supply stores. Remember that the pipe will stretch, and the cable will not. Leave a slight excess length of cable between each wrap as illustrated.

**WARNING Do not use nylon cable ties in water.** Nylon absorbs water and gets weak after a few years. To bind the pump cable to the drop pipe, use vinyl electrical tape or pipe-wrap tape.

**WARNING when using flexible POLYETHYLENE (PE) pipe, allow for pipe stretch.** Make the cable, probe wires and rope longer than the pipe, to prevent tension when the pipe stretches.

cable & wires – 1.5% longer than pipe
rope – 1 % longer than pipe

Distribute the excess length along the length of the pipe (as illustrated) and leave a little more excess length around the splice.

If the water is highly mineralized or has high biological activity, you may choose to hang the low-water probe separately from the pipe, cable and rope, so it can be pulled up separately for inspection or service. See Section 5.9 Low Water Probe.



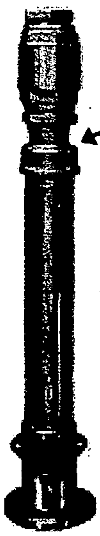
92

## 6.4 Installation in a Surface Water Source

This refers to a surface well, spring, pond, lake, river or tank.

**Positioning the pump** The pump may be placed in an inclined or horizontal position if desired. To reduce the intake of sediment, do not place the intake very close to the bottom.

**CAUTION The pump must be fully submerged.** A helical rotor pump may overheat and stop (temporarily) if the pump end is not fully submerged.



Models 03, 03H, 04 and 04H have a small "vent hole" near the top of the pump (see photo.) If the hole is not submersed, it will suck air and prevent the pump from performing fully. The purpose of this hole is to allow water to fill a gap, so it can conduct heat out of the rubber stator.

VENT HOLE HERE, must be submersed (models 03, 03H, 04 and 04H only)

**River or stream** Secure the pump from logs and debris that may float downstream. Use stainless steel wire rope or chain instead of plastic safety rope (plastic rope will weaken in sunlight). Consider digging a shallow well near the stream. This will allow filtration of the water through the earth, and will protect the pump from floating debris or human tampering.

**Position of the low-water probe** In case of a horizontal installation, the low-water probe (if used) must be relocated to a vertical position, above the intake.

**WARNING High water temperature can cause failure to start.** This can occur in surface water during hot weather. The product specifications say: TEMPERATURE LIMITS: Optimum water temp. is 46°F to 72°F (8°C to 22°C). Higher temp. may cause the pump to stop temporarily due to expansion of the rubber stator. Higher and lower temp. ranges are available by special order.
**If you are in doubt about the pump you received, contact your supplier before installation.**

**Is a flow sleeve required?** NO, not within the normal temperature range. The *ETAPUMP* high-efficiency motor generates very little heat. A conventional submersible pump requires a flow sleeve to assist motor cooling when installed in open water (not confined by a narrow casing). It is a piece of 4-6" pipe that surrounds the pump to increase flow around the motor.

**Depth of submersion** *ETAPUMP* may be submersed as deep as necessary to ensure reliable water supply. The lift load on the pump is determined by the vertical head of water starting at the SURFACE of the water in the source. Increasing the submergence of the pump (placing it lower in the source) will NOT cause it to work harder or to pump less water. Avoid placing the pump close to the bottom where it will pick up sediment.

**Filtration at the pump intake** *ETAPUMP* will tolerate small amounts of sand, but you may need to filter out larger debris that is normally found in a pond or stream. You can construct a simple coarse screening system to protect the pump and to reduce the nuisance of debris in your water system. We have found a fabric material that makes a very effective screen, and does not tend to clog frequently. It is WEED BARRIER FABRIC, available from local nursery and landscaping suppliers. Use a very coarse, loosely woven fabric. The pump can be wrapped with about 6-8 layers of this fabric. A better method is to construct a pump enclosure from 4-6" plastic pipe, with perforations to let water in. Then, wrap the fabric around the enclosure.

**WARNING for SIPHON APPLICATIONS** If a pump system has a vertical lift of less than 33 feet up from the surface of the water source, and then the water flows downhill to a lower point, a siphon effect may cause suction on the pump. This will cause an upward thrust on the motor shaft, resulting in damage to the motor. Prevent this by installing an air vent or a vacuum breaker at the high point on the pipe.



93

## 6.5 Deep Well Setting — How Deep?

*ETAPUMP* may be submersed as deep as necessary to ensure reliable water supply. The lift load on the pump is determined by the vertical head of water starting at the SURFACE of the water in the source. Increasing the submergence of the pump (placing it lower in the well) will NOT cause it to work harder or to pump less water, nor will it increase the stress or wear on the pump.

There are reasons NOT to set the pump near the bottom of the well, if it isn't necessary:
1. A deep setting will increase the size requirements, costs and weight of pipe and cable.
2. A deep setting will increase the chance of sand or sediment being drawn into the pump.

To make an informed decision, it is helpful to have accurate data for your water source. In most places, drillers are required to report the details and the performance of wells that they drill. If you do not have the driller's well record, you may be able to obtain a copy from your regional government office that oversees ground water resources and issues drilling permits. In USA, it is a state office, typically called Department of Natural Resources or State Engineer's Office. However, the data may be missing or inaccurate, and conditions can change over the years. In *critical cases, it is best to have the well re-tested by a water well contractor.*

## 6.6 Coping with Dirty Water Conditions

*ETAPUMP* has good resistance to quantities of sand and fine sediment that can normally occur in a well. However, any amount of abrasive material will reduce the life of the pump. Extreme sediment can cause the pump to stick. Sediment can also settle inside the drop pipe each time the pump stops, and block the flow. For water sources that contain high amounts of sand, clay, or other solids, consider the following suggestions.

**To avoid pumping dirty water**
1. Have your well purged, developed, or otherwise improved by a water well contractor.
2. Temporarily install a larger pump to draw at a high flow rate until silt is purged from the well.
3. Set the pump as high as possible in the well. If the pump can be placed higher than the perforations in the well casing, it will probably avoid all but the finest suspended silt.
4. If the water source is at the surface, dig a shallow well next to the water source to obtain clean water.
5. If the water source is at the surface, use a fabric screen to protect the pump (see Section 6.4).

**If dirty water cannot be avoided**
1. Use a reduced size of drop pipe. This will maximize the velocity of water flow in order to exhaust sand particles. Refer to Section 13.2 Water Pipe Sizing Chart. Select the smallest size pipe that does not impose excessive friction loss. Use a reducer bushing on the pump if necessary, to adapt it to a smaller pipe size.
2. Monitor the situation regularly by observing the volume of water pumped and/or the current draw of the pump (AC amps – see Section 9.3 and 13.7). As a pump wears, its flow rate (and current draw) will decrease gradually. Replace the pump end when reduced performance is observed, or before your season of greatest water demand. Increased current draw may indicate debris stuck in the pump and/or pipe.
3. Before opening a pump that is clogged with dirt, see the CAUTION about removing check valve, Section 9.1.

**Question** *What effect does hard, mineralized, alkaline or salty water have?*
**Answer** *Generally, none. Dissolved minerals and salts are not abrasive.*

## 6.7 Utilizing a Low-Production Water Source

*ETAPUMP* can make the best of a limited water source, even if the pumping rate can exceed the recovery rate. You want to draw the most water possible, without running dry. *ETAPUMP* can handle this in two ways.

**The low-water probe** The low-water probe (included with *ETAPUMP*) allows the pump to work to its full potential until the water level drops (see Section 5.9). This is a good strategy because you get all the water you can while the sun shines. Place the pump near the bottom of the well to utilize the storage of water in the well. When the pump is stopped by the low-water probe, it re-starts after a 20 minute delay. The Low Water OFF light will stay on even after



94

the water recovers and the pump restarts, to indicate that the level got low at some time during the day. See Section 5.9, Low Water Probe. It may be feasible to hang the probe independently and use it to locate the water level at any moment. See Section 6.3, Safety Rope and Binding.

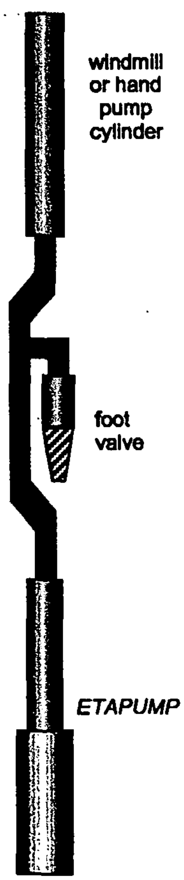
**Reduce the Maximum RPM setting** If the well has little storage capacity, the supply may recover before the 20-minute restart delay. In this case, reduce the "Maximum RPM" setting in the controller. See Section 5.6.

**WARNING Do not use a valve as a means of reducing the flow.** With a helical rotor pump, excessive pressure may result. Use the Maximum RPM setting instead.

**Question** *How is a pump damaged from "dry run"?*
***Answer** If the pump runs completely dry, parts will overheat and be damaged. However, if water is only trickling into the pump, it will usually provide enough lubrication and cooling to prevent damage.*

## 6.8 Installing the Pump Under a Windmill or Hand Pump Cylinder

*ETAPUMP* can be combined with a classic water-pumping windmill or hand pump, to utilize both energy sources automatically. The following system is often used with a conventional AC pump, so a generator can be used for backup. The AC pump is placed immediately below the cylinder, and connected to the cylinder's threaded intake. When power is applied to the AC pump, it pushes water up through the cylinder, pushing its valves open. When the windmill draws water, it sucks it up through the AC pump with little resistance. (The centrifugal pump end of the standard AC pump allows water to flow through it when it is stopped.) When both pumps operate, each one is relieved of its load, more or less.




This system can be employed with *ETAPUMP*. A centrifugal model (one with a "C" in the model number) will allow water to flow freely through it and does NOT require any special precautions. For helical rotor models, the following warning applies.

**WARNING** ***ETAPUMP*** **helical rotor models (those without a "C" in the model number) will NOT allow water to flow freely when stopped. A bypass foot valve must be used.**

To use a helical rotor *ETAPUMP* under a cylinder, you must build a bypass assembly with a T fitting and a foot valve (a check valve with intake screen). When the cylinder's flow exceeds that of the solar pump, water is sucked in through the foot valve. When the solar pump's flow exceeds that of the cylinder, the foot valve closes and allows the solar pump to work normally and push up through the cylinder.

To make this system for a casing 6" (150 mm) or smaller, an offset using 45° elbows must be carefully constructed, as illustrated. Copper fittings must be used for the bypass assembly due to the limited space in the well casing. Do not use any iron fittings in this assembly.

**ILLUSTRATION** Bypass foot valve assembly with offset elbows to fit a drilled well casing



95

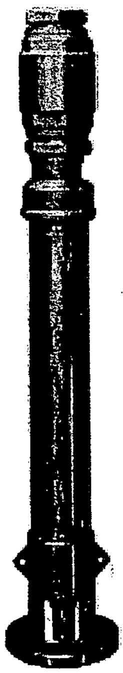
# 7 IN-WELL ASSEMBLY AND INSTALLATION

**SEE REFERENCE SECTION** At the end of this manual (Section 13) you will find instructions for wellhead assembly, water storage, control and monitoring of water supply, pipe sizing, freeze protection, and more.

## 7.1 Rubber Spacers (Models -07, -14, -20 only)

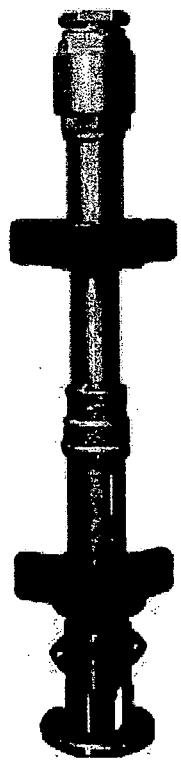
**This applies ONLY to models ETA-07, 14 and 20 (HR-07, 14 and 20 pump ends)**

Helical rotor pumps vibrate due to the eccentric rotation of the helical rotor. This is normal. Rubber spacers reduce the vibration that may be transferred to the well casing. Models –03 and –04 vibrate only slightly so they are not supplied with rubber spacers.



**← PHOTO**
These helical rotor models do NOT have rubber spacers:
ETA-03 (HR-03)
ETA-04 (HR-04)
ETA-04H (HR-04H)

**PHOTO →**
These models have rubber spacers:
ETA-07 (HR-07)
ETA-14 (HR-14)
ETA-20 (HR-20)



**Clearance for drilled well casings** Rubber spacers fit a 6" (150 mm) inside-diameter or larger well casing.

**Cut the rubber spacer legs shorter** if you are installing the pump in a smaller well casing. Grooves indicate where to cut for a 4" (100 mm) casing. Use a fine-tooth saw to cut the rubber.

**WARNING The threads in the check valve require an adhesive sealant.** They are not tapered pipe thread. Normally, there is no reason to remove the check valve. If you do remove it, use a hardening adhesive sealant or epoxy glue when you replace it. See CAUTION in Section 9.1.

## 7.2 Machine Installation

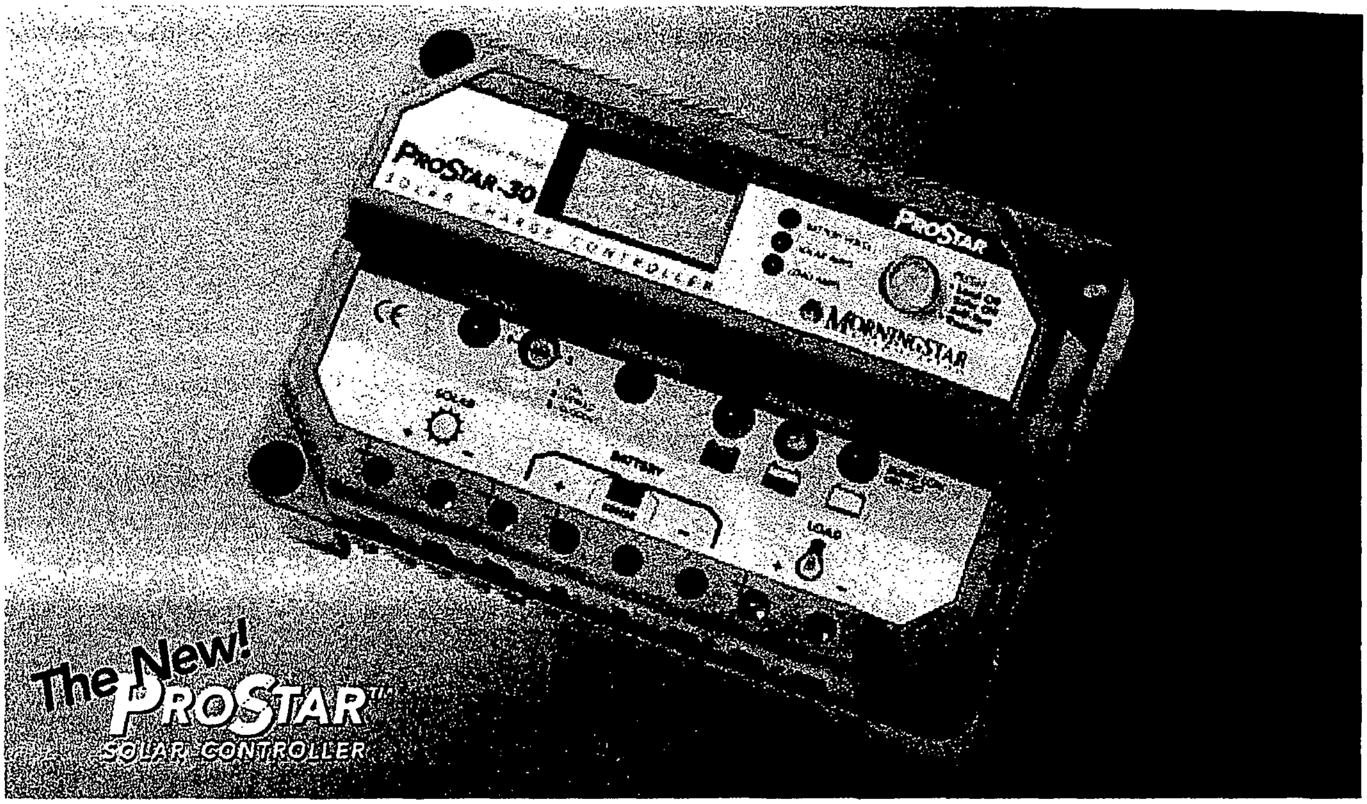
If you are professionally equipped to install conventional AC submersible pumps, you can use the same equipment and methods for *ETAPUMP*. *ETAPUMP* has no special pipe requirements. You can use any suitable rigid or flexible pipe. The only exception is to consider reducing the pipe size in cases of high sand concentration (to increase flow velocity). See Section 6.2 Drop Pipe, and Section 13.2 Water Pipe Sizing Chart.



96

# B.10 Morningstar Prostar 30 Charge Controller Literature

MORNINGSTAR corporation




Morningstar's **ProStar** is the world's leading mid-range solar controller for both professional and consumer applications. This second generation ProStar:

- Adds new features and protections using highly advanced technology
- Provides longer battery life and improved system performance
- Sets new standards for reliability and self-diagostics

## *Standard Features:*

- Versions available: 15 or 30 amp
  12 / 24 or 48 volt
  negative or positive ground
- Estimated 15 year life
- PWM series battery charging (not shunt)
- 3-position battery select: gel, sealed or flooded
- Very accurate control and measurement
- Jumper to eliminate telecom noise
- Parallel for up to 300 amps
- Temperature compensation
- Tropicalization: conformal coating, stainless-steel fasteners & anodized aluminum heat sink
- No switching or measurement in the grounded leg
- 100% solid state
- Very low voltage drops
- Current compensated low voltage disconnect (LVD)
- LED's indicate battery status and faults
- Capable of 25% overloads
- Remote battery voltage sense terminals

## *Electronic Protections:*

- Short-circuit — solar and load
- Overload — solar and load
- Reverse polarity
- Reverse current at night
- High voltage disconnect
- High temperature disconnect
- Lightning and transient surge protection
- Loads protected from voltage spikes
- Automatic recovery with all protections

# PROSTAR

SOLAR CONTROLLERS

# OPERATOR'S MANUAL

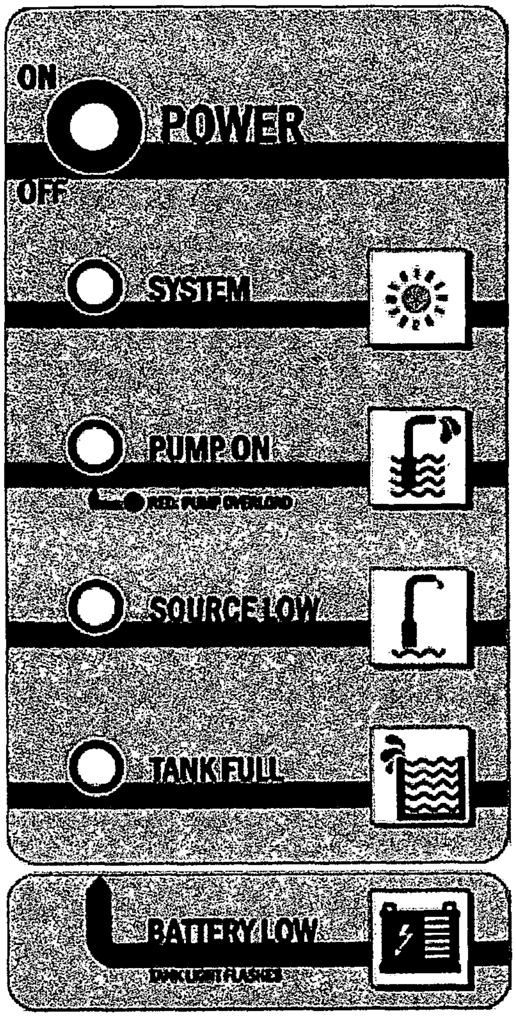
**PROSTAR VERSIONS INCLUDED IN THIS MANUAL**

| | PS-15 | PS-30 | PS-15M-48V |
|---|---|---|---|
| Rated Solar Current | 15A | 30A | 15A |
| Rated Load Current | 15A | 30A | 15A |
| System Voltage | 12/24V | 12/24V | 48V |
| Digital Meter Option | yes | yes | standard |
| Positive Ground Option | no | yes | yes |

MORNINGSTAR corporation
1098 Washington Crossing Road
Washington Crossing, PA 18977 USA
phone: 215 321 4457
fax: 215 321 4458
**email: info@morningstarcorp.com**

# 8 OPERATING THE ETAPUMP

This explains the function of the switch and the indicator lights on the pump controller.




## SWITCH

← **POWER ON/OFF** (PUSH ON / PUSH OFF)
When switched off/on during operation, it resets all system logic.

## INDICATOR LIGHTS

● **SYSTEM (green)**
The controller is switched on and the power source is present. In low-power conditions, the light may show even if there is not enough power to run the pump.

← **PUMP ON (green)**
Motor is turning.
**PUMP OVERLOAD (green changes to red)**
See Troubleshooting, "HIGHER CURRENT", Section 9.3.

← **SOURCE LOW (red)**
The water source dropped below the level of the low-water probe. After the water level recovers, the pump will restart, but this light STAYS ON until the sun goes down, power is interrupted, or the POWER button is reset. This indicates that the water source ran low at least once since the previous off/on cycle.

● **TANK FULL (red)**
Pump is turned off by action of the remote float switch (or pressure switch or manual switch, whichever is wired to the "remote float switch" terminals.

← **BATTERY LOW (tank light flashes)**
**Battery systems only** – battery voltage fell to 22V or 44V, and has not yet recovered to 26V or 52V.

**Starting the pump** Be sure there is not a closed valve or other obstruction in the water line. Switch on the array disconnect switch in the junction box, and press the power switch on the controller. It is normal to leave the switches on at all times, unless you desire to have the system off.

**A solar-direct pump should start under the following conditions**
1. clear sunshine at an angle of about 20° or more from the surface of the solar array
2. cloudy conditions, if the sunshine is bright enough to cast some shadow
3. low-water probe submersed in the water source (or bypassed in the controller) – Water-Low light OFF
4. full-tank float switch is not responding to a full tank – Tank-Full light OFF
5. battery system only – voltage is higher than the low-voltage disconnect point (22V or 44V)

**When sunshine is insufficient** When sunshine on the array is present, but too weak for the pump to run, it will attempt to start about every 90 seconds. During each attempt, you will see the PUMP ON light come on and you may hear a slight noise in the controller.

**When pump runs slowly (PUMP ON) under weak sun conditions**
1. ETAPUMP models that have "C" in the model number – These use a centrifugal pump end. In weak sun, the pump may spin without lifting water all the way to the outlet. This is normal.
2. ETAPUMP models that do NOT have "C" in the model number – These use a helical rotor (positive displacement) pump end. If the pump is turning, even slowly, water will be delivered at a slow rate.



100

**When pump stops from a sudden shadow on the solar array**
If a shadow suddenly passes over the array, like if you walk in front if it, the controller will lose track of the input voltage. It may make rapid on/off noises and a high-pitched noise, then stop. This does NOT indicate a problem. The pump will attempt to restart after the normal delay.

**Time delays**

1. After pump stops due to insufficient sunshine – 15-120 SECONDS
2. After full-tank float switch resets – 15-120 SECONDS (battery systems with ME24/48 controller, a few seconds)
3. After low-water probe regains contact with water in the source – 20 MINUTES but the indicator light will stay on for the rest of the solar day, or until power is disrupted or the controller is turned off/on.
4. Battery systems – after low voltage disconnect point is reached, delay to stop pump – 50 SECONDS. After voltage recovers, delay to re-connect – up to 2 minutes for EP-600 controller, with ME24/48 controller, 50 SECONDS.

**To force a quick start**
To test or observe the system, you can bypass the normal time delays. Switch the POWER switch off then on again. The pump should start immediately if sufficient power is present.

**No-load shutoff**
If the motor is tested without the pump attached, it will run for about 40 seconds, then it will stop. This is the controller's normal response when there is no load on the motor. It will attempt to restart every 30-90 seconds.

**Controller noise** As the pump starts, you may hear slight high-pitched noises from the controller. This is normal.

**Pump vibration** Most *ETAPUMP* models use a HELICAL ROTOR pump end (those that do NOT have a "C" in the model number. A slight vibration is normal with these pumps. If noise is disturbing, try changing the position of the pump. *ETAPUMP* models that have a "C" in the model number use a CENTRIFUGAL pump end similar to conventional pumps. They should produce no significant vibration.

**PUMP OVERLOAD** If the PUMP ON light shows red instead of green, a serious fault has occurred. The motor is unable to turn freely due to a mechanical problem, pipe blockage, or a short circuit. The controller will not reset until power is disconnected for at least 8 seconds. See Troubleshooting, Section 9.3 "HIGHER CURRENT".

**NEW PRODUCT**

***ETAPUMP AC POWER PACK***

This allows the use of 115 or 230VAC power to run ETAPUMP for emergency or supplemental backup. Utility power or a portable generator can be used, and interfaced automatically with solar.

See specification and instruction page in back of this manual.

# 9 TROUBLE SHOOTING

Please read this section before calling for help.
If you call for help, please refer to the model and serial numbers. (See SYSTEM REPORT, page 3.)

See Section 13.7 Obtaining and Using a Multimeter

IF THE CONTROLLER MUST BE REMOVED FOR REPAIR OR REPLACEMENT –
Remove the wires and flexible conduit from the controller and remove the CONTROLLER ONLY.
LEAVE THE JUNCTION BOX IN PLACE.

## 9.1 If The Pump Doesn't Run

Most problems are caused by wrong connections (in a new installation) or failed connections, especially where a wire is not secure and falls out of a terminal. The *System ON* light will indicate that system is switched on and connected to the controller. It indicates that VOLTAGE is present but (in a solar-direct system) there may not be sufficient power to start the pump. It should attempt to start at intervals of 60-90 seconds.

**Pump attempts to start every 60-90 seconds but doesn't run**
The controller makes a slight noise as it tries to start the pump. The pump will start to turn or just vibrate a little.

1. There may be insufficient power reaching the controller. A solar-direct (non-battery) system should start if there is enough sun to cast a slight shadow. A battery system should start if the supply voltage is greater than 22V (24V system) or 44V (48V system).
2. If the pump was recently connected (or reconnected) to the controller, it may be running in reverse direction due to wiring error. See Section 5.8.
3. If the motor shaft only vibrates and will not turn, it may be getting power on only two of the three motor wires. This will happen if there is a broken connection or if you accidentally exchanged one of the power wires with the ground wire. See Section 9.3, testing the motor circuit and the controller output.
4. The pump or pipe may be packed with mud, sediment or debris.
5. Helical rotor models: The rubber stator may be expanded from heat, due to sun exposure or pumping water that is warmer than 100°F (38°C). This may stop the pump temporarily, but will not cause damage.
6. Helical rotor models: The pump may have run dry. Remove the pump stator (outer body) from the motor, to reveal the rotor. If there is some rubber stuck to the rotor, the pump end must be replaced.
7. Helical rotor models: The check valve on the pump may be faulty or stuck, allowing downward leakage when the pump is off. This can prevent the pump from starting.

**PUMP OVERLOAD** This red light indicates a serious fault. The motor cannot turn freely due to a mechanical cause or blockage of the water line. To attempt to restart the pump, disconnect the power for at least 8 seconds. See end of Section 9.3, "HIGHER CURRENT".

**CAUTION DO NOT REMOVE THE CHECK VALVE from the pump.** If you want to look for dirt stuck inside the pump, it is preferable to unbolt the pump body and pull it from the pump. IF YOU MUST REMOVE THE CHECK VALVE, use a hardening adhesive sealant on the screw threads when you replace it. Epoxy glue is good. The threads are not tapered. They will leak if a hardening sealant is not used. Teflon tape will make a good seal, but it may not prevent the joint from unscrewing. If you have questions, call Dankoff Solar Products.

## 9.2 Inspect The System

Many problems can be located by simple inspection. No electrical experience is required for this.

**Inspect the solar array**

1. Is it facing the sun? (See solar array orientation, Sections 4.4 and 4.5)
2. Is there a partial shadow on the array? If only 10% of the array is shadowed, it can stop the pump!

**Inspect all wires and connections**

1. Look carefully for improper wiring (especially in a new installation).
2. Make a visual inspection of the condition of the wires and connections. Wires are often chewed by animals if they are not enclosed in conduit (pipe).



102

3. Pull wires with your hands to check for failed connections.

**Inspect the controller and junction box**

1. Remove the screws from the bottom plate of the controller. Move the plate downward (or the controller upward) to reveal the terminal block where the wires connect. (See Section 5.5.)
2. First, check for a burnt smell. This will indicate a failure of the electronics. Look for burnt wires, bits of black debris, and any other signs of lightning damage.
3. Open the junction box. Is the Power IN switch turned ON? Pull on the wires to see if any of them have come loose.
4. Inspect the grounding wires and connections! Most controller failures are caused by an induced surge from nearby lightning where the system is NOT effectively grounded. Ground connections must be properly made, tight, and free of corrosion. (See Section 5.2.)

**Check the low-water probe (See Section 5.9)**

The probe system works by applying 5VDC to the controller's probe terminals. Conductivity through the water, between the probe causes that voltage to draw down. If the probe voltage is between 0 and 2.8V, the system "sees water" and allows the pump to run. If it is between 2.8V and 5V, conductivity is insufficient and the dry shutoff is triggered.

1. The low-water probe contains two stainless steel electrodes connected to two wires.
2. The probe is normally clamped to the top of the pump. Inspect it if you can.
3. Did the probe or the probe wire break? To test, bypass it by connecting a small wire between the probe terminals in the junction box. Restart the controller. If the pump runs, there is a fault at the probe or in the probe wiring. You can also measure the voltage at the probe terminals. 5V indicates dry probes or a broken connection.
4. Does the pump run when the probe is OUT of the water? This can happen if it is coated with wet sediment, minerals, bacteria or algae. These deposits, can provide a conductive path that makes the probe "think" it is in the water.
5. If deposits on the probe are a problem, see Section 5.9.
6. After years of operation, a probe electrode may be "eaten away" by electrochemical action, especially in highly mineralized water. It will continue to function however, until the metal is practically gone. If the damaged electrode still has most of its material, you can reverse the polarity of the probe connections and the other one will take the damage instead. It is best however to replace the probe.
7. In rare cases, water may be so pure that it doesn't conduct sufficiently between the probes. In this case, the probe terminal voltage will be higher than 2.8V even when wet. For a solution, request *ETAPUMP* Technical Bulletin – Low Water Probe Does Not Detect Water.

**Check the full-tank float switch**

1. Inspect the float switch (if there is one). Is it stuck in the UP position?
2. There are two types of float switch, normally-open and normally-closed. Check to see that the wiring is correct for the type that is used. (See Section 5.10)
3. Most float switches are normally-open. Disconnect one float switch wire from the controller and the pump should run. Jump a wire from the N.O. to the COM. terminal and the pump should stop.

**Force a quick start**

If you restore a connection or bypass the probe or float switch, there is no need to wait for the normal time delay. Switch the on/off switch (or the power source) off then on again. The pump should start immediately if sufficient power is present.

## 9.3 Test The System

**CAUTION: If you test the pump in a bucket – helical rotor models 03, 03H, 04, 04H only**

For these models, you must submerge or temporarily seal the small "vent hole" under the check valve (see photo, section 6.4). Otherwise, the hole will suck air and prevent the pump from working. This will do no damage. If you can't submerse it, seal it temporarily with your finger or a piece of tape.

**Test the solar array circuit**

1. OPEN-CIRCUIT VOLTAGE You can do this easily by opening and switching off the array disconnect switch. The reading should be 72-96V (with a 48V nominal array) or 55-72V (with 36V nominal solar array). This should vary only slightly with solar intensity. This is merely "idle" voltage. It is high because no current is being drawn (it sees no load).



/03

2. VOLTAGE UNDER LOAD (with pump running) This should be 60-73V (with a 48V nominal array) or 45-55V (with 36V nominal solar array). This should vary only slightly with solar intensity.
3. CURRENT UNDER LOAD Measuring current is the way to determine if the solar array's output is equal to its full potential. This requires either a DC clamp-on amp meter or a conventional meter wired in series with the array circuit (by breaking either + or – connection and running the circuit through the meter). The current is determined by both the array AND the load in the circuit (the pump system). If the pump is not drawing full power, it will not draw full current.
4. SHORT CIRCUIT CURRENT and SPARK TEST This will give you an indication of the array output independent of the pump system. This is helpful if the pump is trying to start or does not seem to be getting full power. CAUTION DISCONNECT THE ARRAY from the controller before making this test. Short-circuiting the array will not cause damage if it is done for a minute or less. You can do this easily by switching off the array disconnect switch. You should see a blue spark when short-circuiting the solar array exposed to sunshine. (Unlike other power generators, a short circuit at the array will only cause current slightly higher than normal.) If you don't have a DC amp meter, a spark that can jump 1/4" (6 mm) indicates a good probability that the array is working properly.

**If power was connected to the controller with reverse polarity**

Reverse polarity (+/–) at the controller's POWER IN terminals will be blocked. No lights will show on the controller. This will not cause damage.

**Test the controller power output (measure AC voltage to pump)**

1. Make these tests with the pump connected and the power turned on. Observe caution!
2. Use an AC voltmeter or a multimeter set to AC volts. (Any AC meter should be sufficient. It does not need to be a "true RMS" meter.)
3. Measure between each combination of two pump wires (L1–L2 / L1–L3 / L2–L3).
4. Voltage should be 15-50VAC. It will depend on the system and the voltage, and (in the case of solar-direct systems) will vary with the sun intensity. Each reading should be equal.

**Test the motor circuit (resistance test with power off)**

This resistance test will confirm the condition of the entire motor circuit, including the motor, pump cable and splice. Make this test if there is proper voltage at the controller input but the motor does not run.

1. Disconnect power from the controller.
2. Disconnect at least two of the three pump power wires from the junction box terminals.
3. Use a multimeter set on resistance (RX1 or Ω).
4. Measure between each combination of two pump wires (L1–L2 / L1–L3 / L2–L3).
5. The resistance should be .1 to 1.5 ohm (Ω), depending on the length and size of the pump cable. EACH READING MUST BE EQUAL.
6. NOTE — Resistance between meter probes and wires can produce an erroneous reading. Hold the probes tightly to the wire and scratch them to ensure good contact. Hold them still until the meter display shows the LOWEST reading that you can get. Holding the probes with your fingers will not alter the reading.
7. Measure resistance between the ground wire and the motor wires. Your meter should show either no reading, or more than 100 MΩ (that means 100 million Ω or 100 megohms). A lower reading indicates an insulation fault in a power wire to the pump.

**Test the current draw of the motor circuit (AC amps)**

This is one of the most useful trouble shooting techniques because it indicates the torque that the motor is applying to the pump. Readings must be taken with an AC ammeter (amp meter) or a multimeter with the appropriate capacity. (See Section 13.7.) Measure the current through any one of the three power wires between controller and pump. (If the pump runs, you can assume that all three draw equal current.) For greatest ease, use a clamp-on ammeter, available from local electrical equipment suppliers. It allows you to measure current without breaking connections. The alternative is to use the 10 amp or 20 amp scale on a multimeter. To do that, you must break one connection and cause the current to flow THROUGH the meter.

**Table of AC RUNNING CURRENT** For helical rotor pumps, normal running current indicated on this table. (This is typical actual current, not motor's amp rating.) The current stays nearly constant as voltage and speed vary. Your measurements may vary by as much as 10%, and more if temperature is out of the normal range. Comparing your reading with this table. This will indicate whether the work load on the motor is normal for the lift it is producing. Make note of your measurement. Future changes may indicate pump wear, or change in the level of the water source.



104

| AC RUNNING CURRENT in any one motor wire helical rotor models at 60°F (16°C) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LIFT | *8* | *15* | *23* | *30* | *38* | *46* | *53* | *61* | *76* | *91* | *107* | *122* | *137* | *152* | *167* | *180* | *195* | *210* | *meters* |
| PUMP | **25** | **50** | **75** | **100** | **125** | **150** | **175** | **200** | **250** | **300** | **350** | **400** | **450** | **500** | **550** | **600** | **650** | **700** | **feet** |
| **ETA-03H** | 2.0 | 2.2 | 2.3 | 2.4 | 2.5 | 2.7 | 2.9 | 3.0 | 3.3 | 3.9 | 4.1 | 4.3 | 4.5 | 4.8 | 5.0 | 5.2 | 5.6 | 5.8 | |
| **ETA-04H** | 2.0 | 2.2 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.6 | 4.0 | 4.4 | 4.9 | 5.3 | 5.8 | 6.2 | 6.9 | | | | **AC** |
| **ETA-04** | 1.4 | 1.6 | 1.9 | 2.1 | 2.4 | 2.6 | 2.9 | 3.1 | 3.6 | 4.1 | 4.7 | | | | | | | | **AMPS** |
| **ETA-07** | 2.3 | 2.7 | 3.1 | 3.4 | 3.8 | 4.2 | 4.5 | 5.0 | 5.7 | 6.4 | 7.2 | 7.9 | 8.7 | | | | | | |
| **ETA-14** | 2.7 | 3.7 | 4.5 | 5.3 | 6.3 | 7.1 | 7.9 | 9.0 | | | | | | | | | | | |
| **ETA-20** | 3.7 | 4.8 | 6.1 | 7.3 | 8.5 | | | | | | | | | | | | | | |

**HIGHER CURRENT (especially PUMP OVERLOAD light) may indicate:**

1. The pump may be handling excessive sediment (sand, clay).
2. The total dynamic head (vertical lift plus pipe friction) may be higher than you think it is.
3. There may be an obstruction to the water flow — sediment in the pipe, ice in the pipe, a crushed pipe or a partially closed valve. (Is there a float valve at the tank?)
4. Helical rotor models: Water may be warmer than 72°F (22°C). This causes the rubber stator to expand and tighten against the rotor (temporarily, non-damaging). See Section 12 for temperature limits.
5. Helical rotor models: Pump may have run dry. Remove the pump stator (outer body) from the motor, to reveal the rotor. If there is some rubber stuck to the rotor, the pump end must be replaced.

To reset the OVERLOAD shutoff (red light), disconnect the power for at least 8 seconds.

**LOWER CURRENT may indicate:**

1. In a deep well, the level of water in the source may be far above the pump intake, so the actual lift is less than you think. This is not a problem.
2. The pump head may be worn, thus easier to turn than normal (especially if there is abrasive sediment).
3. There may be a leak in the pipe system, reducing the pressure load.
4. Helical rotor models: Water may be colder than 46°F (8°C). This causes the rubber stator to contract, away from the rotor. The pump spins easier and produces less flow under pressure.

## 9.4 If The Pump Runs But Flow Is Less Than Normal

1. Is the solar array receiving shadow-free light? (It only takes a small shadow to stop it.) Is it oriented properly toward the south, and tilted at the proper angle? See Section 0.
2. Be sure you have the right pump for the total lift that is required, out of the well + up the hill. In the case of a pressurizing system, the pressure head is equivalent to additional lift (1 PSI = 2.31 feet) (1 bar = 10 m).
3. Be sure all wire and pipe runs are sized adequately for the distance. Refer to wire sizing in the pump sizing table, and to the pipe sizing chart in this manual, reference section.
4. Inspect and test the solar array circuit and the controller output, as above. Write down your measurements.
5. There may be a leak in the pipe from the pump. Open a pipe connection and observe the water level. Look again later to see if it has leaked down. There should be little or no leakage over a period of hours.
6. Measure the pump current and compare it with the table in the previous section.
7. There is a "max. RPM" adjustment in the controller. It may have been set to reduce the flow as low as 50%. See Section 5.6.

**Has the flow decreased over time?**

1. Is the AC motor current lower than normal? Motor starts and runs easily in low light? The pump end (pump mechanism attached to motor) may be worn from abrasive material (sand, silt, clay) in the water. Is sediment accumulating in the water tank or pipes?
2. Is the AC motor current higher than normal? Doesn't start easily in low light? This is likely to be related to dirt in the pump and/or pipe.
3. Run the pump in a bucket to observe.
4. Remove the pipe from the pump outlet (check valve) and see if sand or silt is blocking the flow.
5. If the check valve itself is clogged with dirt, call Dankoff Solar for help.
6. To help prevent dirt problems, see Section 6.6 Coping With Dirty Water Conditions.

# 9.5 PROBLEM REPORT (tear-out page)

If you need help, this form will expedite the trouble shooting process. Please fill it in to the best of your knowledge.

**CONTACT INFO** **DATE**__________

Dealer's name: ______________________________
Installer's name: ______________________________
System owner's name: ______________________________
Person doing the trouble shooting: ______________________________
How to contact: ______________________________

**PUMP SYSTEM ID**

Solar-direct or battery system? ____________ See "System Report Form", Section 2
Pump or System Model #: ____________
Pump Model number ________ Serial #: __________
Controller Model # _________ Serial #: __________

**IF BATTERY SYSTEM:**

Voltage ____
Is it pressurizing? __________

**WELL/WATER SOURCE DATA**

Well depth: ____________________
Static water level: _________
Drawdown level: ________
Recovery rate of well: ________
Depth of pump setting: _______
Additional vertical lift from top of well: ______
Total head: ____________

Installation Date: ____/____/_______
Drop pipe length & size: _________
Pipe from wellhead to tank length & size: ______
Pump cable size & length: _________________
Wiring from solar array to controller size and length: ___________________________

**DESCRIBE THE PROBLEM**

If pump won't start, include sequence and duration of the indicator lights.

_______________________________________________________________
_______________________________________________________________
_______________________________________________________________
_______________________________________________________________
_______________________________________________________________
_______________________________________________________________

Was the Pump tested before installation? _____________
Did the system work properly before this problem? ____________

Has there been a thunderstorm recently? ___________

Has the RPM control in the controller been reduced from maximum? __________



106

## ETAPUMP PROBLEM REPORT — PAGE 2

### ELECTRICAL MEASUREMENTS

Weather conditions during measurement: ________________________ Time of day: _____:_____ AM/ PM

Solar array DC volts with PUMP OFF ________VDC (Measure at PV IN terminals in junction box, switch OFF)
Solar array DC volts during pumping ________VDC
Solar array DC current (amps) during pumping _______ Amps DC

IF THE PUMP RUNS, make the following three tests. If not, skip to RESISTANCE MEASUREMENT below.
Measure AC amps through any one motor wire (a normal AC clamp-on meter will work).
(Normal range for working pump is 1 - 9 amps.) ________

AC volts on pump terminals in controller
Measure 3 phases by measuring each pair L1-L2, L1-L3, L2-L3
EACH READING MUST BE EQUAL. Wait until the pump is up to speed to check for equal.
L1-L2________; L1-L3________; L2-L3________

DC Volts on 3 motor phases — YES, set the meter to DC and test as above.
Around than 1/10V is good. Around 1/2V is bad. Note here if bad: _________

RESISTANCE MEASUREMENT
This will test the integrity of the motor and the wiring to it. This is done with NO POWER applied. If you are not familiar with measuring resistance, please refer to your meter's instruction manual. You will need to use the lowest ohms range on your meter. Hold the probes tightly to the wires and scratch then a little to ensure good contact. Hold tight until the meter display shows the LOWEST reading that you can get. Holding the probes with your fingers will not alter the reading.
DISCONNECT the three motor wires (L1 / L2 / L3) from the junction box.
Measure the resistance between each pair on the motor cable L1-L2 ______Ω L1-L3 ______Ω L2-L3 ______Ω.
The resistance must be in the range of .1 to 1.5 ohms — ALL EQUAL.

Resistance of each pump wire to ground – There should be NO continuity. A meter reading should be much higher than 100K ohms. DO NOT TOUCH the wires or probes with your fingers when reading this high range, or your own body continuity will reduce the reading.

### WATER TEMPERATURE
Is the water warmer than 72°F (22C)? This can cause a helical rotor to tighten due to expansion of the rubber stator. Temperature _______

### SOLAR-DIRECT SYSTEMS
Is there ANY OTHER electrical load or device connected to the same solar array? This may include an active (electric) solar tracker or an electric fence charger —> disconnect it and try it again.

### OTHER INFORMATION:



107

# 10 MAINTENANCE

## 10.1 Controller and Pump

**Controller and junction box** The controller is electronic with no moving or wearing parts. It requires no maintenance. There are rubber gasket seals at the top and bottom, and rubber plugs to seal unused conduit holes. Inspect them to insure that the controller is sealed from moisture, insects, etc. Check that mounting and conduit hardware is tight.

**Motor** The motor is water-lubricated and requires no maintenance. It is permanently sealed and has no brushes or other frequently wearing parts.

**Pump end** The pump mechanism (pump end) is lubricated only by water and requires no maintenance. It may wear after some years, especially if there are abrasive solids in the water. If sand accumulates in the storage tank or pipes as a result of normal pumping, it is best to take periodic measurement of the pump's performance. If the flow rate is less than normal, see Section 9.4. A worn pump end can be replaced in the field, after the pump is pulled from the water source.

## 10.2 Solar Array

**Solar array mounting bolts** Bolts tend to loosen as the array structure flexes in high winds. Check tightness. All bolts should all have lock washers to keep them tight.

**Sun exposure** Cut away any vegetation that will grow enough to block solar illumination. Shading even a small corner of the solar array may stop the pump, or greatly reduce its flow.

**Solar array cleaning** If there is dirt, mineral deposits, bird droppings or other debris stuck to the solar array surface, clean it with water, vinegar or glass cleaner.

**Solar Array Tilt** Inspect the tilt of the array. The optimum tilt angle varies with the season. Some people adjust the tilt twice per year. Other people set it at a single setting as a permanent compromise. Section 4.5 for details.

**Solar Tracker** If the system uses a solar tracker, lubricate the bearings, check mounting bolts and mechanism. Refer to tracker manufacturer's instructions. On a passive tracker, the shock absorber(s) may fail every few years. To test, swing the tracker by hand. It should return slowly due to damping action of the shock absorber. If it returns immediately (and swings in the wind) replace the shock absorber(s).

## 10.3 Electrical Wiring

**Power wiring** Inspect wires and connections carefully. Any wires that are hanging loose should be secured to prevent them from swinging in the wind. Exposed wiring must be sunlight resistant and in good condition. In the case of a tracking array, look carefully for any wire damage due to rubbing, bending, or pulling as the tracker swings. If wiring was not performed to professional standards, improve it to prevent faults in the future.

**Grounding** Inspect the grounding system carefully. All connections must be tight and free of corrosion. Poor grounding can lead to damage from lightning-induced surges. See Section 5.2.

# 11 ETAPUMP MANUFACTURER'S WARRANTY

***ETAPUMP*® pumps, motors and controllers are warranted by the manufacturer to be free from defects in material and workmanship for two (2) years from date of purchase.**

**When purchased as part of an *ETAPUMP INTEGRATED SYSTEM*™ supplied directly or indirectly by Dankoff Solar Products, Inc., the pump and controller warranty is extended to four (4) years by the manufacturer.**

Failure to provide correct installation, operation, or care for the product, in accordance with the instruction manual, will void the warranty. Product liability, except where mandated by law, is limited to repair or replacement, at the discretion of the manufacturer or importer.

Neither manufacturer nor importer is responsible for the labor or other charges necessitated by the removal, transportation, or reinstallation of any defective product.

Warranty does not cover damage due to failure to install the device properly, mishandling or abuse, failure to protect circuitry from weather exposure, failure to protect from overheating due to sun exposure or other sources of heat, failure to protect from salt spray or other corrosive factors, failure to seal out insects, spiders or rodents, lightning, flood or other acts of nature, or failure of or inappropriate application of peripheral devices including lightning or surge protectors.

Warranty does not cover damage due to sand or abrasive particles in the water, or incompatibility of pump materials with corrosive substances or hydrocarbon or petroleum impurities, or from running the pump with an insufficient supply of water.

No specific claim of merchantability shall be assumed or implied beyond what is printed on the manufacturer's or importer's printed literature. No liability shall exist from circumstances arising from the inability to use the product, or its inappropriateness for any specific purpose. It is the user's responsibility to determine the suitability of the product for any particular use.

In all cases, it shall be the responsibility of the customer to ensure a safe installation in compliance with local, state and national electrical codes.

# 12 STANDARDS, ENVIRONMENTAL and TEMPERATURE SPECIFICATIONS

*ETAPUMP* controllers are built to DIN-VDE regulations and carry the CE stamp indicating that the European Union electromagnetic interference standards (Dt. EMV) have been fulfilled. Printed circuit boards are conformal-coated against moisture. The enclosure is thick anodized aluminum, gasket-sealed and raintight for any outdoor environment (enclosure class IP55). The controller is suited to tropical conditions according to IEC 68-2-30. The controller is not submersible.

**Temperature Ranges**
Helical rotor pumps (all without C in the model number): For pumps in the standard temperature class, the optimum range of water temperature is 46°F to 72°F (8°C to 22°C). Higher temperature may cause the pump to stop temporarily due to expansion of the rubber stator. Exceeding the limit may cause the pump to stop temporarily due to expansion of the rubber stator. This will not cause damage. Operation in water colder than 45°F (7°C), may decrease the pumping capacity temporarily due to contraction of the rubber stator, especially if the vertical lift is close to the pump's limit. Non-standard temperature classes are available by special order. See Section 2, "Temperature ranges".

Controller: Ambient air temperature -22°F to 113°F (-30°C to 45°C). The controller has over-temperature protection.

**Other system components** The PV modules (solar panels) in the *ETAPUMP Integrated System*™ (complete PV-direct systems supplied by Dankoff Solar Products) are UL-listed and carry other international certifications.



109

# 13 REFERENCE SECTION

## 13.1 Principles of Operation

**Solar array** Photovoltaic (PV) cells produce electricity directly from sunlight (not from heat). Light causes electrons to jump from the top layer of the cell, into "holes" in the layer underneath. When a circuit is made between top and bottom layers, electric current flows. Each cell produces about 1/2 volt. As sunlight varies, the current (amps) varies while the voltage stays nearly constant.

PV cells are connected in series for the desired voltage, and sealed under glass to make a "PV module". *ETAPUMP* systems use 3 to 12 modules. The assembly of modules is called a "PV array". There are no moving or wearing parts in PV modules. The glass used in high quality PV modules is tempered, and is extremely strong. It is tested to federal standards that include resistance to a 1" ice ball traveling at 100 mile per hour.

Some *ETAPUMP* systems use a "passive" solar tracker, which tilts the array to follow the sun through the day. The east and west sides of the tracker rack contain refrigerant fluid. The fluid in the warmer side of the frame vaporizes, and condenses in the cooler side. This tips the balance of the rack until it reaches equilibrium, facing the sun. The performance of a passive tracker is not perfect, but it is simple, reliable, and extremely effective.

**Brushless motor system** *ETAPUMP* uses a brushless DC motor system consisting of a synchronous, permanent magnet, 3-phase AC motor, and a controller that changes the solar DC power to 3-phase AC. AC creates a rotating magnetic field that causes the shaft to spin. The motor's speed is determined by the frequency of the AC power. The controller varies the frequency (and the voltage) to bring the motor up to speed slowly. It then adjusts the motor speed according to the power available from the sun.

Older-technology solar pumps have a traditional DC motor that uses "brushes" (small blocks of carbon-graphite) to conduct current to the spinning part of the motor. Not only do the brushes wear out in a few years, but it is necessary to have air in the motor and a perfect seal to keep water out. The *ETAPUMP* brushless motor is filled with, and lubricated by water. It is similar mechanically to conventional AC submersible motors.

**Controller (EP-600 for solar-direct operation)** The controller starts the pump slowly and adjusts its speed according to the pumping load and the power available from the solar array. Power output from the array is optimally matched to the load by *maximum power point tracker* (MPPT) and *linear current booster* (LCB) functions, to produce maximum power transfer throughout all conditions. The LCB function is analogous to an automatic transmission in an automobile. It starts the pump in "low gear" (it lowers the array voltage and boosts the current). Under low sun conditions, it stays in "low gear" to resist stalling. As sunlight increases, it advances continuously toward "high gear" (higher voltage). The MPPT system refines the LCB function by tracking changes in the array voltage. Array voltage varies primarily with temperature (it is higher at low temperatures). When the pump stalls in low sunlight, the controller switches the pump off.

The controller converts the DC power from the solar array to 3-phase AC power to run the motor. Motor speed (RPM) is proportional to the AC frequency. The frequency starts low (about 20 Hz), and increases gradually to a maximum of 3400 RPM (70 Hz).

The float switch circuit operates at 12VDC, carrying maximum current of 4.7mA. The controller has terminals for either normally open (N.O.) or normally closed (N.C.) switching.

The low-water probe circuit applies 5VDC to a probe. The water conducts a small amount of current between the two electrodes of the probe. If the probe is out of the water, the controller stops the pump. When the water level recovers, there is a 20 minute delay before restart.

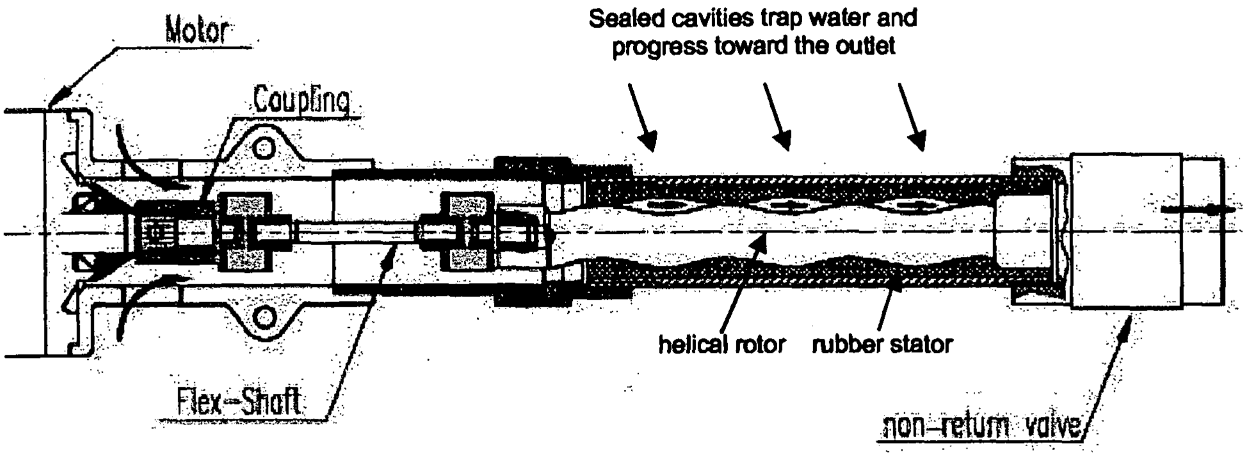
**Pump end – centrifugal models** Pumps with a MODEL NUMBER CONTAINING "C" use a multi-stage centrifugal pump end, similar to that of conventional well pumps – this is for high volume at 75 feet (23m) or less.

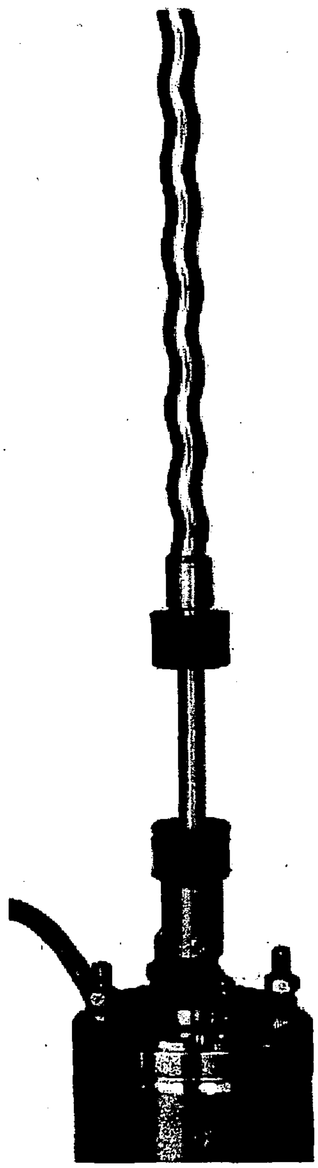
**Pump end – helical rotor models** Pumps with a MODEL NUMBER THAT DOES NOT CONTAIN "C" have a helical rotor pump end (also called "progressive cavity" pump). The rotor fits closely into a rubber stator that has a helical groove of a different pitch. The mismatch between the rotor and stator forms sealed cavities that trap water. As the rotor turns, the cavities progress toward the outlet.



110

## *ETAPUMP* – HELICAL ROTOR MODELS ONLY



**Positive displacement action** The helical rotor pump differs from centrifugal pumps in that it maintains high efficiency and lift capacity even at low rotational speeds and low flow rates. This allows *ETAPUMP* to work with a small, inexpensive solar array, and to function in low sunlight conditions.

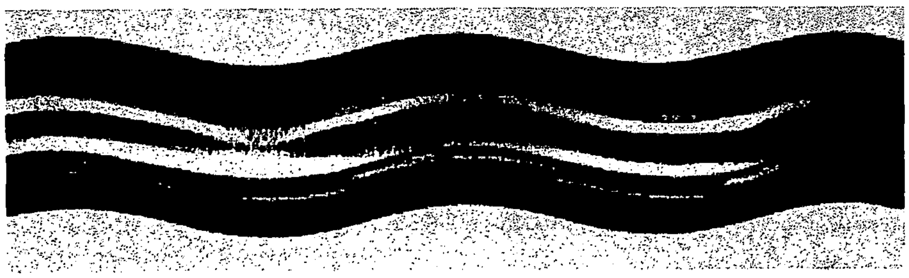
**The *ETAPUMP* helical rotor has only one moving part.** It produces a smooth flow and requires no valves to function. It is far more reliable than diaphragm and piston-type solar pumps.

**Self-cleaning action** The rotor sweeps the full surface of the rubber stator with every turn. It is impossible for deposits to accumulate. Solid particles tend to roll away from the contact area, making the pump extremely resistant to abrasion. Particles that are trapped against the rubber are tolerated by the flexibility of rubber.

**Some history** Helical rotor pumps have been used in the oil industry for over 60 years. They are used to pump concrete! They have been used for solar pumping since the 1980's, but were very expensive until *ETAPUMP* was introduced.

**PHOTO LEFT** — Motor with helical rotor attached, stator housing removed.

**PHOTO BELOW** — Close-up of the same rotor. This is a test specimen that pumped extremely sandy water for 500 hours in the test lab. The surface is almost like new, and the pump performs to full specifications.





111

# 13.2 Water Pipe Sizing Chart

**Don't cheat yourself with undersized pipe!** Use this chart to determine the additional head imposed on your pump due to pipe friction, based on flow rate, pipe size and pipe length. Consider the TOTAL pipe length from the pump to the pipe outlet to the tank.

**Pipe fittings** impose additional friction loss. A sharp 90° pipe elbow adds friction approximately equal to 6 feet (2m) of pipe of the same size.

**Friction Loss in Plastic Pipe with Standard Inside Diameter (SIDR)**
THIS CHART APPLIES ONLY TO: PVC pipe, Schedule 40 (160 PSI) and to polyethylene (PE) pipe with SIDR designation (most common 100 PSI black flex pipe)

**HEAD LOSS from friction in feet per 100 feet of pipe or vertical meters per 100 meters of pipe**

| FLOW RATE | | NOMINAL PIPE DIAMETER (Inches) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1/2*** | **3/4** | **1** | **1 1/4** | **1 1/2** | **2** | **2 1/2** | **3** | **4** | **5** | **6** |
| **GPM** | ***LPM*** | *0.662* | *0.82* | *1.05* | *1.38* | *1.61* | *2.07* | *2.47* | *3.07* | *4.03* | *5.05* | *6.06* |
| | | | | | | | | | *actual inside diameter (inches)* | | | |
| 1 | *3.8* | 1.13 | 0.14 | 0.05 | 0.02 | | | | | | | |
| 2 | *7.6* | 4.16 | 0.35 | 0.14 | 0.05 | 0.02 | | | | | | |
| 3 | *11.4* | 8.55 | 2.2 | 0.32 | 0.09 | 0.05 | | | | | | |
| 4 | *15* | 14.8 | 3.7 | 0.53 | 0.16 | 0.09 | 0.02 | | | | | |
| 5 | *19* | | 5.8 | 0.81 | 0.25 | 0.12 | 0.05 | | | | | |
| 6 | *23* | | 7.9 | 1.0 | 0.35 | 0.18 | 0.07 | 0.02 | | | | |
| 7 | *27* | | 10.6 | 1.5 | 0.46 | 0.23 | 0.08 | 0.03 | | | | |
| 8 | *30* | | 13.4 | 1.9 | 0.58 | 0.30 | 0.09 | 0.05 | | | | |
| 9 | *34* | | | 2.4 | 0.72 | 0.37 | 0.12 | 0.06 | | | | |
| 10 | *38* | | | 2.9 | 0.88 | 0.46 | 0.16 | 0.07 | 0.02 | | | |
| 11 | *42* | | | 3.5 | 1.04 | 0.53 | 0.18 | 0.08 | 0.03 | | | |
| 12 | *45* | | | 4.1 | 1.2 | 0.65 | 0.21 | 0.09 | 0.04 | | | |
| 14 | *53* | | | | 1.6 | 0.85 | 0.28 | 0.12 | 0.05 | | | |
| 16 | *61* | | | | 2.1 | 1.1 | 0.37 | 0.14 | 0.06 | | | |
| 18 | *68* | | | | 2.6 | 1.3 | 0.46 | 0.18 | 0.07 | | | |
| 20 | *76* | | | | 3.2 | 1.6 | 0.55 | 0.21 | 0.08 | 0.02 | | |
| 22 | *83* | | | | 3.8 | 2.0 | 0.67 | 0.25 | 0.09 | 0.03 | | |
| 24 | *91* | | | | | 2.3 | 0.79 | 0.30 | 0.12 | 0.04 | | |
| 26 | *99* | | | | | 2.7 | 0.90 | 0.35 | 0.14 | 0.05 | | |
| 28 | *106* | | | | | 3.1 | 1.0 | 0.42 | 0.16 | 0.05 | | |
| 30 | *114* | | | | | 3.5 | 1.2 | 0.46 | 0.18 | 0.06 | | |
| 35 | *133* | | | | | | 1.6 | 0.62 | 0.23 | 0.07 | | |
| 40 | *152* | | | | | | 2.0 | 0.79 | 0.30 | 0.09 | 0.02 | |
| 45 | *171* | | | | | | 2.5 | 0.97 | 0.37 | 0.12 | 0.04 | |
| 50 | *190* | | | | | | 3.0 | 1.2 | 0.46 | 0.14 | 0.05 | |
| 55 | *208* | | | | | | 3.6 | 1.4 | 0.55 | 0.16 | 0.06 | |
| 60 | *227* | | | | | | | 1.7 | 0.65 | 0.18 | 0.07 | 0.02 |
| 65 | *246* | | | | | | | 1.9 | 0.74 | 0.22 | 0.08 | 0.03 |
| 70 | *265* | | | | | | | 2,2 | 0.85 | 0.25 | 0.09 | 0.04 |
| 75 | *284* | | | | | | | 2.5 | 0.97 | 0.28 | 0.10 | 0.05 |
| 80 | *303* | | | | | | | | 1.1 | 0.32 | 0.12 | 0.06 |
| 85 | *322* | | | | | | | | 1.2 | 0.37 | 0.14 | 0.07 |
| 90 | *341* | | | | | | | | 1.4 | 0.39 | 0.15 | 0.08 |
| 95 | *360* | | | | | | | | 1.5 | 0.44 | 0.16 | 0.09 |
| 100 | *379* | | | | | | | | | 0.49 | 0.18 | 0.12 |
| 150 | *569* | | | | | | | | | 1.0 | 0.37 | 0.16 |
| 200 | *758* | | | | | | | | | 1.8 | 0.62 | 0.28 |

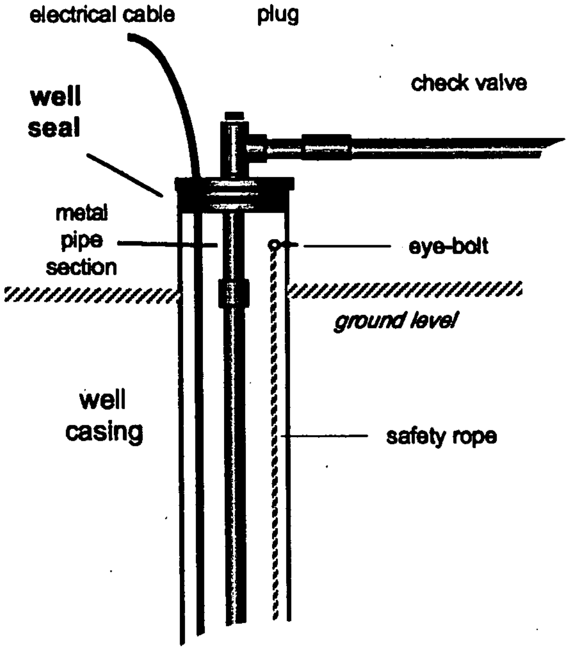
* 1/2" data applies to polyethylene pipe only. PVC has smaller ID of .612"

Courtesy of Dankoff Solar Products, Inc.



112

# 13.3 Wellhead Assemblies for Drilled Wells




### To support the drop pipe and seal the wellhead, choose one of these methods

These methods are NOT specific to solar pumps. The components are available from conventional water well suppliers.

### ← Well Seal System

The well seal is a plate that fits on top of the well casing. It provides a seal against contamination, and it supports the weight of the in-well assembly. In a freezing climate, the wellhead must be located in a heated building or in a covered well pit, or the pipe must be made to drain when the pump stops (see Section 13.6 Freeze Protection).

Use metal pipes above ground, for strength. A tee and a plug is used instead of an elbow, because the plug allows direct observation of water level and flow. It also provides a place to attach a lifting device.

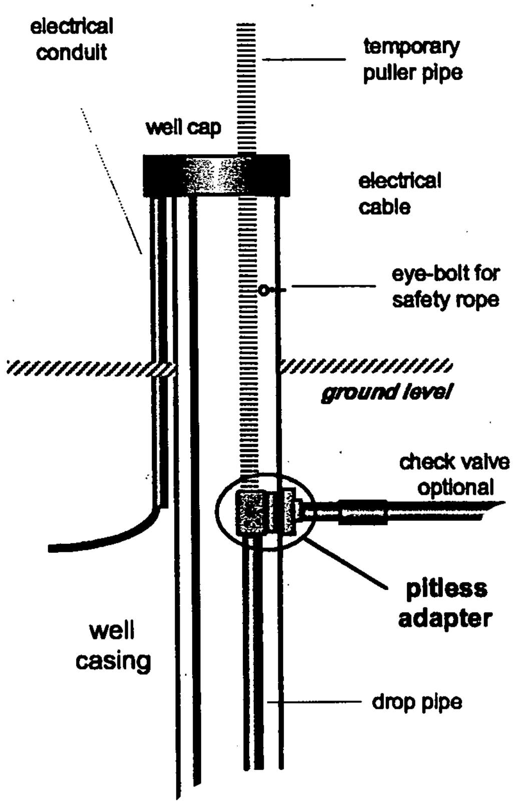
### Pitless Adapter System →

The pitless adapter is a fitting that allows your buried pipe to pass through the well casing underground, without the need to build a covered pit. It provides protection against freezing, flooding, animals and human activities that can damage exposed piping.

After the pitless adapter is installed, the pump can be installed and removed from above, with no further need to dig. The inside half slides apart vertically by means of a dovetail joint and an O-ring. A piece of threaded pipe is used as a temporary tool for installation or removal. Thread it into the socket on the inside half of the adapter.

If the well casing is 4" (inside diameter) the pitless adapter must be designed not to reduce the clearance inside the casing (it clamps around the outside of the casing).

**Two pumps in one well** If you have a well casing of 6" or larger, you may be able to install two pumps in the well, by using two pitless adapters.




### Check Valve

A check valve (non-return valve) prevents stored water from escaping down the well in case of a leak in your drop pipe. It may also help the pump to start easier if it feeds into a very long pipeline. If you use a weep hole for freeze protection, omit this check valve to allow the pipe to drain.

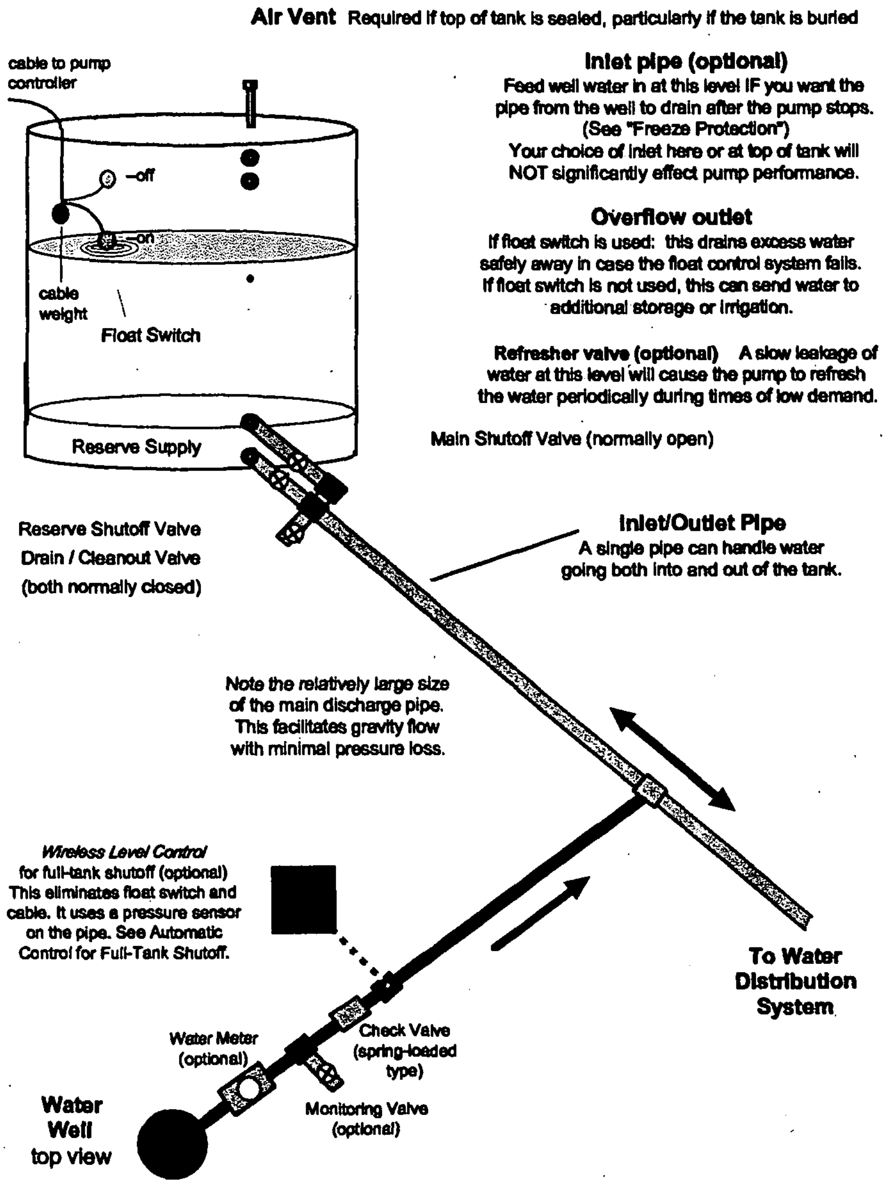


113

# 13.4 Water Storage for Solar Water Pumps

### Storage Tank Capacity

Generally, storage capacity should equal 3 to 10 days of average water consumption, or more. This depends on the climate and usage patterns. For domestic use in a cloudy climate, 10 days is minimal. In a sunny climate, this allows for a generous safety margin. For deep irrigation of trees (where the soil holds moisture for a week) 3 days' storage may be adequate. For irrigating a garden, 5 days may be adequate. You cannot store too much water!




### Storage Tank Plumbing

We suggest that you place your normal point of discharge higher than the bottom of your water tank, in order to hold a reserve so that the tank does not run completely dry.

You can lose your water supply under any of these conditions:

1. a period of low sunshine and/or excessive water demand
2. an electrical or mechanical failure in the system
3. a leak in the tank or piping
4. an accidental discharge of stored water

Place a second outlet valve at the bottom level of your storage tank, to use the *reserve supply in case of emergency.*

**Pipe sizing** The pipe from the pump to the tank may need to be larger than the pump outlet, depending on the flow and the length of pipe. A single pipe may be used for both fill and discharge. In that case, size the pipe for the maximum discharge that you want to accomplish. You may oversize the pipe if there is a chance that you may install a second pump, or larger pump in the future. Sizing the pipe larger than necessary will NOT influence the performance of the system. See Section 13.2, Water Pipe Sizing Chart.

If you plan to use gravity-flow to supply water from the storage tank, be sure the discharge pipe is large enough to allow sufficient flow to meet the maximum water demand without excessive friction loss.

**Pressure of delivery** Every 2.3 feet vertical feet of drop produces 1 PSI of pressure, minus any friction loss (10m produces 1 bar). The volume of water stored in the tank does not effect the pressure delivered.

**Water Purification** Check local health authorities and/or plumbing codes to ensure you will comply with requirements for using a storage tank that is open to the atmosphere, for potable water. Sanitation by means of chlorination, ozone or infrared system may be required or recommended.



114

## 13.5 Monitoring a Solar Pump System

**Monitoring the pump** Will you be able to observe the output of your pump at the point of discharge? If not, you may not know if it malfunctions. Consider installing a water meter, or additional valves so that the flow can be directly observed. (See illustration in Section 13.4)

**Monitoring the water level in your storage tank** Will you be able to observe the level of water in your tank? If you cannot easily see into your storage tank, here are some methods of tank monitoring.

1. dipstick in the air vent
2. float with a visible rod that protrudes through the top of the tank
3. clear sight-tube alongside the tank
4. precision pressure gauge (note: 1 PSI = 2.3 feet)
5. "*Wireless Level Controller*" (see Section 5.10).

## 13.6 Freeze Protection for Solar Water Pumps

In a cold climate, water can freeze in a pipe and block the water flow. This will cause an electrical overload that will cause the pump to stop.

**Pressure relief** If there is any possibility of a pipe freezing, install a pressure relief valve to prevent excess pressure in the pump line. Install it below frost line. Adjust the valve to open if the pressure exceeds normal. This is especially important for helical rotor pumps (model number not containing "C") which can develop very high pressure.

**Burial of pipe** The best way to prevent freezing is to bury all piping below frost line. The modern method of burial at the wellhead is to install a pitless adapter (see section 13.3, Wellhead Assemblies for Drilled Wells).

**Will the pump drain back when it stops?** NO! The pump has a check valve that stops water from draining back down when it stops. A helical rotor pump will not drain back even if the check valve is removed.

**WARNING Do not install the pump with its check valve removed.**

**Weep hole** If you have above-ground piping that must be drained for freeze protection, make a tiny "weep hole" in the drop pipe, below frost line. This will cause a constant (but very small) leakage of water back into the well. When the pump stops, the pipe will drain back slowly. The pipe must be sloped without low spots, so it drains completely. In plastic pipe, a weep hole can be made with a hot needle or an extremely small drill bit, or a needle valve can be installed and adjusted.

**Weep hole – "high tech" version** The most reliable way to control dripping is to use a "drip emitter" made for drip irrigation systems. It resists accumulation of debris and mineral deposits far better than a simple hole or a needle valve. Emitters are very inexpensive. They are available from irrigation suppliers, nurseries, and many hardware stores. Drip emitters are rated in very low gallons (liters) per hour. Use a relatively fast one for best reliability, especially if you get mineral deposits. Drill a hole in the pipe to fit the emitter, and push the emitter into the hole.

**Polyethylene pipe** Flexible "poly pipe" (PE) has proven to tolerate repeated freezing. Connections may be loosened by ice expansion, but the pipe is not damaged. Poly pipe is often used in places where pipe may freeze accidentally or occasionally. See Section 7.3 for precautions regarding PE pipe. If you plan to bury PE pipe, observe further precautions supplied by the pipe manufacturer.



115

## 13.7 Obtaining and Using a Multimeter for Trouble Shooting

Most on-site trouble shooting requires a test instrument called a multimeter which can be obtained from an electric supply, electronic supply, automotive or hardware store. It will measure DC and AC volts, current (amps) and resistance (ohms, symbolized by Ω). Here are some criteria for selecting a meter for testing *ETAPUMP* systems.

**Digital or analog (mechanical) meter?** A digital meter is best. An **autoranging digital** meter is easiest to use, especially for a beginner. An analog meter is good if it is of good quality and at least 3" (75 mm) wide.

**Resistance ranges** The meter must read in the 0-10Ω range to one decimal place. This includes all but the smallest and cheapest digital meters, and any analog meter that has at least three resistance ranges.

**Ammeter ranges** These are the options, listed in order of benefit and cost:

1. Milliamp range but no Amp range (under $35 in USA) – This will be useful for voltage and resistance measurement, but not for current. It is sufficient for the most elementary trouble shooting.
2. Amp range to 10A or more, without clamp-on capability – This will measure PV array current and pump running current. A wire must be disconnected in order to measure current (current must flow through the meter).
3. DC/AC clamp-on ammeter – This allows measurement of current without disconnecting wires. We strongly recommend this type of meter if you maintain numerous solar pumps or other electrical equipment. Fluke Model 33 or 36 are the professional favorites. Cheaper ones are much less reliable. AC-only clamp-on meters will NOT measure DC current. However ...
4. AC clamp-on ammeter. An AC-only meter is much less expensive than a DC/AC meter. Most electricians and pump technicians carry one. It cannot be used to test the solar array (DC), but it can be used to measure the pump circuit (AC) for various faults and load conditions. It is very useful.

**"True RMS" accuracy** This feature is NOT necessary for testing *ETAPUMP*.

**Use two meters and clips for easier testing.** It is good to measure voltage and current simultaneously. An inexpensive meter is adequate for voltage, because precision is not necessary. Clip-wires or clip-on probes are very helpful if you don't have three hands.

**Resistance readings** are always taken with NO POWER applied to the circuit. Always use the LOWEST range that produces a reading (RX1 is the lowest range). An "auto-ranging" meter will adjust its range automatically.

**Zero adjustment** Some meters require zero-adjustment to insure accuracy. This applies to analog meters measuring resistance, and to clamp-on DC ammeters. Be sure to set the zero if necessary!

**WARNING Read the instructions that come with your meter, and follow the safety warnings.**

**WARNING Attempting to read current (amps) between the two poles of a power circuit causes a potentially dangerous short circuit. Connect the probes IN SERIES with the circuit – see your meter's instruction manual. To read voltage, the red probe must NOT be in the Amps socket. This will cause a short circuit.**

## 13.8 Measuring Solar Energy Intensity

To evaluate the a solar-direct solar pump, it is very helpful to measure sun intensity. For example, if the solar pump is producing around 60% of the specified maximum flow, and you measure the sun intensity (in the same plane as the array) as 60% of full sun, you know that the system is working properly.

The *Daystar Meter* is a hand-held instrument that measures sun intensity using a PV cell that is similar to those used to power *ETAPUMP*. It displays instantaneous intensity in Watts per square meter (W/m$^2$). The industry-standard for full sun intensity is 1000 W/m$^2$, so a reading of 600 indicates 60% intensity.

The meter costs less than US$150. Order directly from the manufacturer: Daystar, Inc., 3240 Majestic Ridge, Las Cruces, NM 88011 USA, tel. (505) 522-4943 daystarpv@mac.com www.raydec.com/daystar



116

## 13.9 Glossary of Solar Electricity and Water Pumping

**Courtesy of Dankoff Solar Products, Inc.**
2810 Industrial Rd.
Santa Fe, NM USA 87505
(505) 473-3800 www.dankoffsolar.com

### Basic Electricity

**AC** - Alternating Current, the standard form of electrical current supplied by the utility grid and by most fuel-powered generators. The polarity (and therefore the direction of current) alternates. In U.S.A., standard voltages for small water pumps are 115V and 230V. Standards vary in different countries. See *inverter*.
**DC** - Direct Current, the type of power produced by photovoltaic panels and by storage batteries. The current flows in one direction and polarity is fixed, defined as positive (+) and negative (-). Nominal system voltage may be anywhere from 12 to 180V. See *voltage, nominal*.
**Current** - The rate at which electricity flows through a circuit, to transfer energy. Measured in Amperes, commonly called Amps. Analogy: flow rate in a water pipe.
**Efficiency** - The percentage of power that gets converted to useful work. Example: An electric pump that is 60% efficient converts 60% of the input energy into work - pumping water. The remaining 40% becomes waste heat.
**Energy** - The product of power and time, measured in Watt-Hours. 1000 Watt-Hours = 1 Kilowatt-Hour (abbreviation: KWH). Variation: the product of current and time is Ampere-Hours, also called Amp-Hours (abbreviation: AH). 1000 watt consumed for 1 hour = 1 KWH. See *power*.
**Converter** - An electronic device for DC power that steps up voltage and steps down current proportionally (or vice-versa). Electrical analogy applied to AC: See *transformer*. Mechanical analogy: gears or belt drive.
**Inverter** - An electronic device that converts low voltage DC to high voltage AC power. In solar-electric systems, an inverter may take the 12, 24, or 48 volts DC and convert it to 115 or 230 volts AC, conventional household power.
**Power** - The rate at which work is done. It is the product of Voltage times Current, measured in Watts. 1000 Watts = 1 Kilowatt. An electric motor requires approximately 1 Kilowatt per Horsepower (after typical efficiency losses). 1 Kilowatt for 1 Hour = 1 Kilowatt-Hour (KWH).
**Three-Phase AC** - Three phase power is AC that is carried by three wires. Power waves are applied in a sequence. Three-phase is used for large industrial motors, variable-speed motors, and brushless solar water pump motors. Analogy: 3-cylinder engine.
**Transformer** - An electrical device that steps up voltage and steps down current proportionally (or vice-versa). Transformers work with AC only. For DC, see *converter*. Mechanical analogy: gears or belt drive.
**Utility Grid** - Commercial electric power distribution system. Synonym: *mains*.
**Voltage** - The measurement of electrical potential. Analogy: Pressure in a water pipe.
**Voltage Drop** - Loss of voltage (electrical pressure) caused by the resistance in wire and electrical devices. Proper wire sizing will minimize voltage drop, particularly over long distances. Voltage drop is determined by 4 factors: wire size, current (amps), voltage, and length of wire. It is determined by consulting a wire sizing chart or formula available in various reference tests. It is expressed as a percentage. Water analogy: Friction Loss in pipe.
**Voltage, Nominal** - A way of naming a range of voltage to a standard. Example: A "12 Volt Nominal" system may operate in the range of 11 to 15 Volts. We call it "12 Volts" for simplicity.

### Solar Electricity

**Charge Controller** - A device that regulates the charge current to a battery in order to prevent overcharge. It prevents excessive voltage and maximizes the longevity of a battery. It may also contain other control functions (see Low Voltage Disconnect).
**Deep Cycle Battery** - Batteries that are designed to discharge as much as 80% of their capacity, hundreds of times. They differ from engine-starting batteries by having thicker plates and different metal alloys.
**Low Voltage Disconnect** - A control function in a battery-based power system in which the load or loads are disconnected before the battery gets over-discharged. Over-discharge will damage a lead-acid battery. Typical settings for a 12V system are 10.5 or 11V disconnect and 12.5 or 13V reconnect.
**Photovoltaic** - The phenomenon of converting light to electric power. Photo = light, Volt = electricity. Abbreviation: *PV*.
**PV** - The common abbreviation for *photovoltaic*.



117

**PV Array** - A group of PV (photovoltaic) modules (also called *panels*) arranged to produce the voltage and power desired.
**PV Array-Direct** - The use of electric power directly from a photovoltaic array, without storage batteries to store or stabilize it. Most solar water pumps work this way, utilizing a tank to store water.
**PV Cell** - The individual photovoltaic device. Most PV modules are made with around 36 or 72 silicon cells, each producing about 1/2 volt.
**PV Module** - An assembly of PV cells framed into a weatherproof unit. Commonly called a "PV panel". See *PV array.*
**Solar Tracker** - A mounting rack for a PV array that automatically tilts to follow the daily path of the sun through the sky. A "tracking array" will produce more energy through the course of the day, than a "fixed array" (non-tracking) particularly during the long days of summer.
**Voltage, Open Circuit** - The voltage of a PV module or array with no load (when it is disconnected). A "12 Volt Nominal" PV module will produce about 20 Volts open circuit. Abbreviation: Voc.
**Voltage, Peak Power Point** - The voltage at which a photovoltaic module or array transfers the greatest amount of power (watts). A "12 Volt Nominal" PV module will typically have a peak power voltage of around 15-17 volts. The solar array for a PV array-direct solar pump should reach this voltage in full sun conditions, or a multiple of this voltage. Abbreviation: Vpp.

## Pumps & Related Components

**Booster Pump** - A surface pump used to increase pressure in a water line, or to pull from a storage tank and pressurize a water system. See *surface pump.*
**Centrifugal Pump** - A pumping mechanism that spins water in order to push it out by means of centrifugal force. See also *multi-stage.*
**Check Valve** - A valve that allows water to flow one way but not the other.
**Diaphragm Pump** - A type of pump in which water is drawn in and forced out of one or more chambers, by a flexible diaphragm. Check valves let water into and out of each chamber.
**Float Switch** - An electrical switch that responds to changes in water level. It may be used to prevent overflow of a tank by turning a pump off, or to prevent a pump from running dry when the source level is low.
**Float Valve** - A valve that responds to changes in water level. It is used to prevent overflow of a tank by blocking the flow of water.
**Foot Valve** - A check valve placed in the water source below a surface pump. It prevents water from flowing back down the pipe and "losing prime". See *check valve* and *priming.*
**Helical Rotor Pump** - A pump with a helix-shaped rotor that fits closely into a rubber stator that has a helical groove. It forms sealed cavities that trap water. As the rotor turns, the cavities move toward the outlet. See *positive displacement pump.* Synonyms: progressive cavity pump, screw pump.
**Impeller** - The device that spins inside of a centrifugal pump, in order to develop centrifugal force.
**Jet Pump** - A surface-mounted centrifugal pump that uses an "ejector" (venturi) device to augment its suction capacity. In a "deep well jet pump", the ejector is down in the well, to assist the pump in overcoming the limitations of suction. (Some water is diverted back down the well, causing an increase in energy use.)
**Multi-Stage Centrifugal** - A centrifugal pump with more than one impeller and chamber, stacked in a sequence to produce higher pressure. Conventional AC deep well submersible pumps and some solar submersibles work this way.
**Positive Displacement Pump** - Any mechanism that seals water in a chamber, then forces it out by reducing the volume of the chamber. Examples: piston, diaphragm, helical rotor, vane. Used for low volume and high lift. Contrast with *centrifugal.* Synonyms: volumetric pump, force pump.
**Priming** - The process of hand-filling the suction pipe and intake of a surface pump. Priming is generally necessary when a pump must be located above the water source. A *self-priming* pump is able to draw some air suction in order to prime itself, at least in theory. See *foot valve.*
**Pulsation Damper** - A device that absorbs and releases pulsations in flow produced by a piston or diaphragm pump. Consists of a chamber with air trapped within it or a length of flexible tube.
**Pump Jack** - A deep well piston pump. The piston and cylinder is submerged in the well water and actuated by a rod inside the drop pipe, powered by a motor at the surface. This is an old-fashioned system that is still used for extremely deep wells, including solar pumps as deep as 1000 feet.
**Self-Priming Pump** - See *priming.*
**Submersible Pump** - A motor/pump combination designed to be placed entirely below the water surface.
**Surface Pump** - A pump that is not submersible. It must be placed no more than about 20 ft. above the surface of the water in the well. See *priming.* (Exception: see *jet pump*)



118

## Solar Pump Components

**DC Motor, Brush-Type** - The traditional DC motor, in which small carbon blocks called "*brushes*" conduct current into the spinning portion of the motor. They are used in most solar surface pumps and in some low-power solar submersibles. The motor chamber must be filled with air and perfectly sealed from moisture. Brushes naturally wear down after years of use, and must be replaced periodically.
**DC Motor, Brushless** - High-technology motor used in more advanced solar submersibles. An electronic system is used to precisely alternate the current, causing the motor to spin. See *three-phase AC*. A submersible brushless motor is filled with water and requires no maintenance.
**DC Motor, Permanent Magnet** - All DC solar pumps use this type of motor in some form. Being a variable speed motor by nature, reduced voltage (in low sun) produces proportionally reduced speed, and causes no harm to the motor. Contrast: *induction motor*
**Induction Motor (AC)** - The type of electric motor used in conventional single-phase AC water pumps. It requires a high surge of current to start, and a stable voltage supply, making it relatively expensive to run from by solar power. See *Inverter.*
**Linear Current Booster (LCB)** - An electronic device which varies the voltage and current of a PV array to match the needs of an array-direct pump, especially a *positive displacement* pump. It allows the pump to start and to run under low sun conditions without stalling. Electrical analogy: variable transformer. Mechanical analogy: automatic transmission. Also called *pump controller.* See *pump controller*.
**Maximum Power Point Tracking (MPPT)** - An added refinement in some linear current boosters, in which the input voltage tracks the variations of the output voltage of the PV array to draw the most possible solar power under varying conditions of temperature, solar intensity and load.
**Pump Controller** - An electronic device that controls or processes the power to a pump. It may perform any of the following functions: stopping and starting the pump; protection from overload; DC-to-AC conversion; voltage conversion; power matching (see *linear current booster).* It may also have provisions for low-water shutoff and full-tank shutoff devices, and status indicators.

## Water Well Components

**Borehole** - Synonym for drilled well, especially outside of North America.
**Casing** - Plastic or steel tube that is permanently inserted in the well after drilling. Its size is specified according to its inside diameter.
**Cable Splice** - A joint in electrical cable. A submersible splice is protected by a water-tight seal.
**Drop Pipe** - The pipe that carries water from a pump in a well, up to the surface. It also supports the pump.
**Perforations** - Slits cut into the well casing to allow groundwater to enter. May be located at more than one level, to coincide with water-bearing strata in the earth.
**Pitless Adapter** - A special pipe fitting that fits on a well casing, below ground. It lets the pipe pass horizontally through the casing so that no pipe is exposed above ground where it could freeze. The pump may be installed and removed without further need to dig around the casing. This is done by using a 1" threaded pipe as a handle.
**Safety Rope** - Rope used to secure the pump in case of pipe breakage.
**Submersible Cable** - Electrical cable designed for in-well submersion. Conductor sizing is specified in square millimeters, or (in North America) by American Wire Gauge (AWG) in which a higher number indicates smaller wire. It is connected to a pump by a *cable splice*.
**Well Seal** - Top plate of a well casing that provides a sanitary seal and support for the drop pipe and pump. Alternative: *See pitless adapter*

## Water Well Characteristics

**Driller's Log** - The document on which well characteristics are recorded by the well driller. In most states, drillers are required to register all water wells and to send a copy of the log to a state office. This supplies hydrological data and well performance test results to the well owner and the public. Synonym: *well record.*
**Drawdown** - Lowering of level of water in a well due to pumping.
**Drawdown level** - Depth to the water surface in a well while it is being pumped.
**Recovery Rate** - Rate at which groundwater refills the casing after the level is drawn down. This is the term used to specify the production rate of the well.
**Static Water Level** - Depth to the water surface in a well under static conditions (not being pumped). May be subject to seasonal changes or lowering due to depletion.
**Wellhead** - Top of the well.



119

## Pump System Engineering

**Friction Loss** - The loss of pressure due to flow of water in pipe. This is determined by 4 factors: pipe size (inside diameter), pipe material, flow rate, and length of pipe. It is determined by consulting a friction loss chart available in an engineering reference book or from a pipe supplier. It is expressed in PSI or Feet (equivalent additional feet of pumping). Pipe fittings, especially 90° elbows, impose additional friction.
**Head** - See synonym: *vertical lift*.
**Suction Lift** - Applied to surface pumps: Vertical distance from the surface of the water in the source, to a pump located above the surface. This distance is limited by physics to around 20 feet at sea level (subtract 1 ft. per 1000 ft. altitude) and should be minimized for best results.
**Submergence** - Applied to submersible pumps: Distance below the static water level, at which a pump is set.
**Total Dynamic Head** - *vertical lift* + *friction loss* in piping (see *vertical lift* and *friction loss*).
**Vertical Lift** - The vertical distance that water is pumped. This determines the pressure that the pump pushes against. Total vertical lift = vertical lift from surface of water source up to the discharge in the tank + (in a pressure system) discharge pressure. Synonym: *static head*. Note: Horizontal distance does NOT add to the vertical lift, except in terms of pipe friction loss. NOR does the volume (weight) of water contained in pipe or tank. Submergence of the pump does NOT add to the vertical lift. See *total dynamic head*.

## Water Distribution

**Cut-In Pressure** and **Cut-Out Pressure** - See *pressure switch*.
**Gravity Flow** - The use of gravity to produce pressure and water flow. A storage tank is elevated above the point of use, so that water will flow with no further pumping required. A booster pump may be used to increase pressure. 2.31 vertical feet = 1 PSI. 10 vertical meters = 1 bar. See *pressure*.
**Head** - See*vertical lift* and *total dynamic head*. In water distribution, synonym: *vertical drop*. See *pressure*.
**Open Discharge** - The filling of a water vessel that is not sealed to hold pressure. Examples: storage (holding) tank, pond, flood irrigation. Contrast: *pressure tank*.
**Pressure** - The amount of force applied by water that is either forced by a pump, or by the gravity. Measured in pounds per square inch (PSI) or bar (atmospheres). PSI = vertical lift (or drop) in Feet / 2.31. 1 Bar = 10 vertical meters.
**Pressure Switch** - An electrical switch actuated by the pressure in a pressure tank. When the pressure drops to a low set-point (cut-in) it turns a pump on. At a high point (cut-out) it turns the pump off.
**Pressure Tank** - A fully enclosed tank with an air space inside. As water is forced in, the air compresses. The stored water may be released after the pump has stopped. Most pressure tanks contain a rubber bladder to capture the air. If so, synonym: captive air tank.
**Pressure Tank Precharge** - The pressure of compressed air stored in a captive air pressure tank. A reading should be taken with an air pressure gauge (tire gauge) with water pressure at zero. The air pressure is then adjusted to about 3 PSI lower than the cut-in pressure (see Pressure Switch). If precharge is not set properly, the tank will not work to full capacity, and the pump will cycle on and off more frequently.



## 13.10 Handy Facts & Formulae

Vertical Lift is measured from the <u>surface</u> of the water source to the pump outlet or the water level in the storage tank (whichever is higher) + pipe friction loss.
The load on the pump is <u>not</u> affected by the volume of water in the pipe or in the tank!

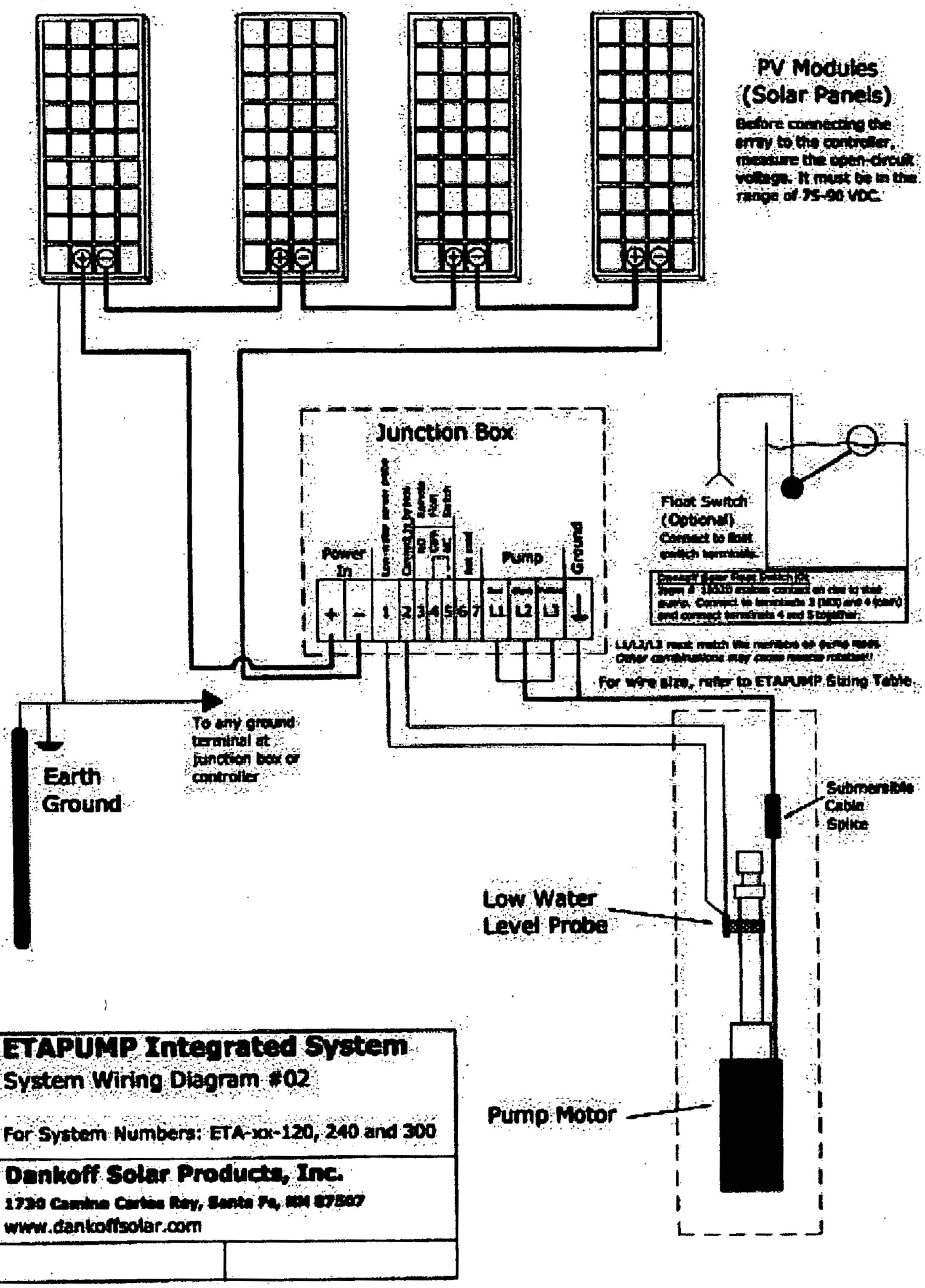
A 48V pump requires 1/4 the wire size of a 24V pump for the same power (watts).

$$\text{Amps} = \frac{\text{Watts}}{\text{Volts}} \qquad \text{PSI} = \frac{\text{Vert. Feet}}{2.31} \qquad \text{\% Efficiency of any pump} = \frac{\text{Vert. Lift, Feet} \times \text{GPM} \times 18.8}{\text{Watts}}$$

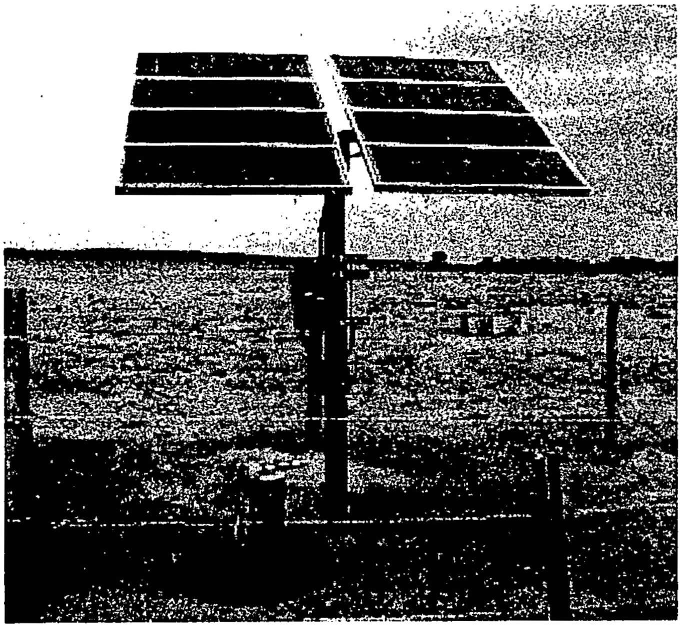


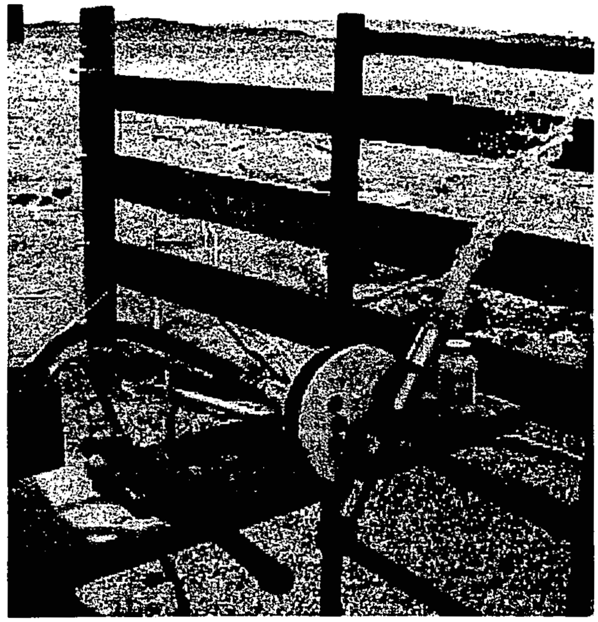
120

***ETAPUMP Integrated System*,** **System Wiring Diagram** This is a sample diagram representing a typical solar-direct system using 4 X 12V-nominal PV modules. Your system may vary in the number, voltage, and configuration of PV modules. If the diagram for YOUR system is not attached here, request it from your *ETAPUMP* supplier.




**This manual is the property of the *ETAPUMP* owner. Please give it to the owner or maintenance personnel when you are finished! Request copies from your supplier or download from www.dankoffsolar.com**

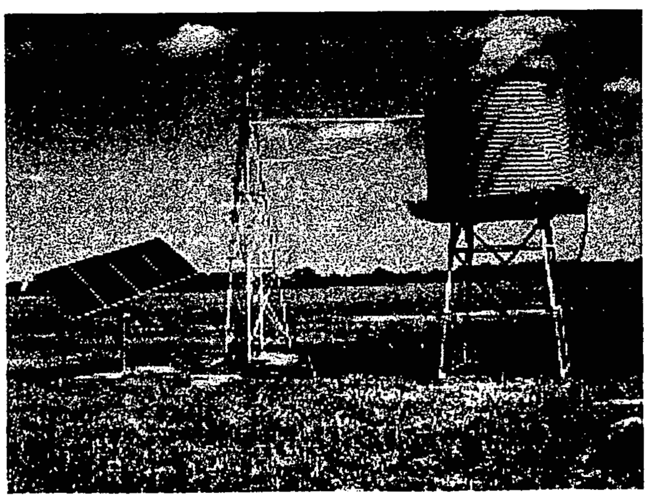




Ranch installation in Colorado, USA
Installation by RA Power Co.
(Canyon City, Colorado)

# ETAPUMP®

Windmill replacement in Western Australia
Installation by BW Solar (Perth, Australia)



ETAPUMP passes flow test at a Cambodian orphanage
Installation by Arjen Luxwolda for Pico Sol

# B.7 ETAPUMP® HR (Helical Rotor) Specifications

# ETAPUMP® HR Helical Rotor

## Submersible Pumps for Conventional AC Power Sources

Dankoff Solar

**The most efficient well pump in the world**

**Lifts from as deep as 600 feet**

**HALF the power of conventional pumps**

**Self-cleaning, resists clogging**

**Highly resistant to sand and corrosion**

## HIGH EFFICIENCY = LOWER ENERGY COST

ETA is a Greek letter that engineers use to represent ENERGY EFFICIENCY.

*ETAPUMP HR* has TWICE the energy efficiency of a conventional pump. It uses a positive displacement helical rotor (progressive cavity) mechanism instead of a multi-stage centrifugal. It can pump from very deep wells with a smaller motor and lower energy cost.

## RELIABLE AND MAINTENANCE-FREE

Helical rotor pumps have been used in oil wells since the 1940's. They are so tough, they are used to pump concrete! *ETAPUMP HR* takes this mechanism to a new standard of precision, efficiency and economy.

## SOLVES THE TOUGHEST WATER PROBLEMS

*ETAPUMP HR* has 100% self-wiping action. Nothing can stick to the pumping surfaces. It resists corrosion, mineral accumulation, bacterial slime, and other problems that stop conventional pumps.

## HANDLES LOW-PRODUCTION SOURCES

*ETAPUMP HR* can pump very slowly, with proportionally low power draw. This is far more efficient than a conventional pump that must start and stop frequently.

## SPECIFICATIONS

**VOLTAGE**
- 60Hz AC Single phase
- Model HR-04-115VAC: 115V
- All others: 230V

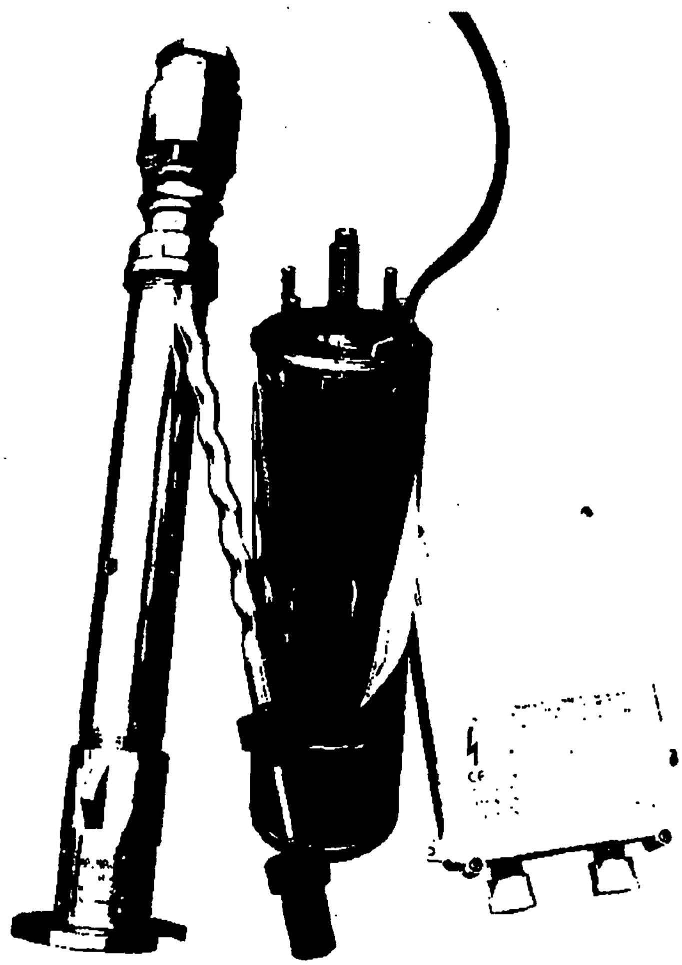
**PIPE SIZE**
- HR-04 and HR-07: 1" outlet
- HR-14: 1 1/4" outlet

**DIMENSIONS & WEIGHT**
- Diameter: 3.78" *(96mm)*
- Height: 20"-32" *(500-800mm)* depending on model
- Weight: 25lbs (11.5kg) or less, depending on model

**WETTED MATERIALS**
stainless steel 304, 316, 440B, brass (check valve only, 2% Pb), chromium, NBR rubber, natural rubber

**TEMPERATURE LIMITS**
The optimum working range of water temperature is 45-77°F (7-25°C). The pump will draw more power and may stop at around 104°F (40°C). For other temperatures, inquire.

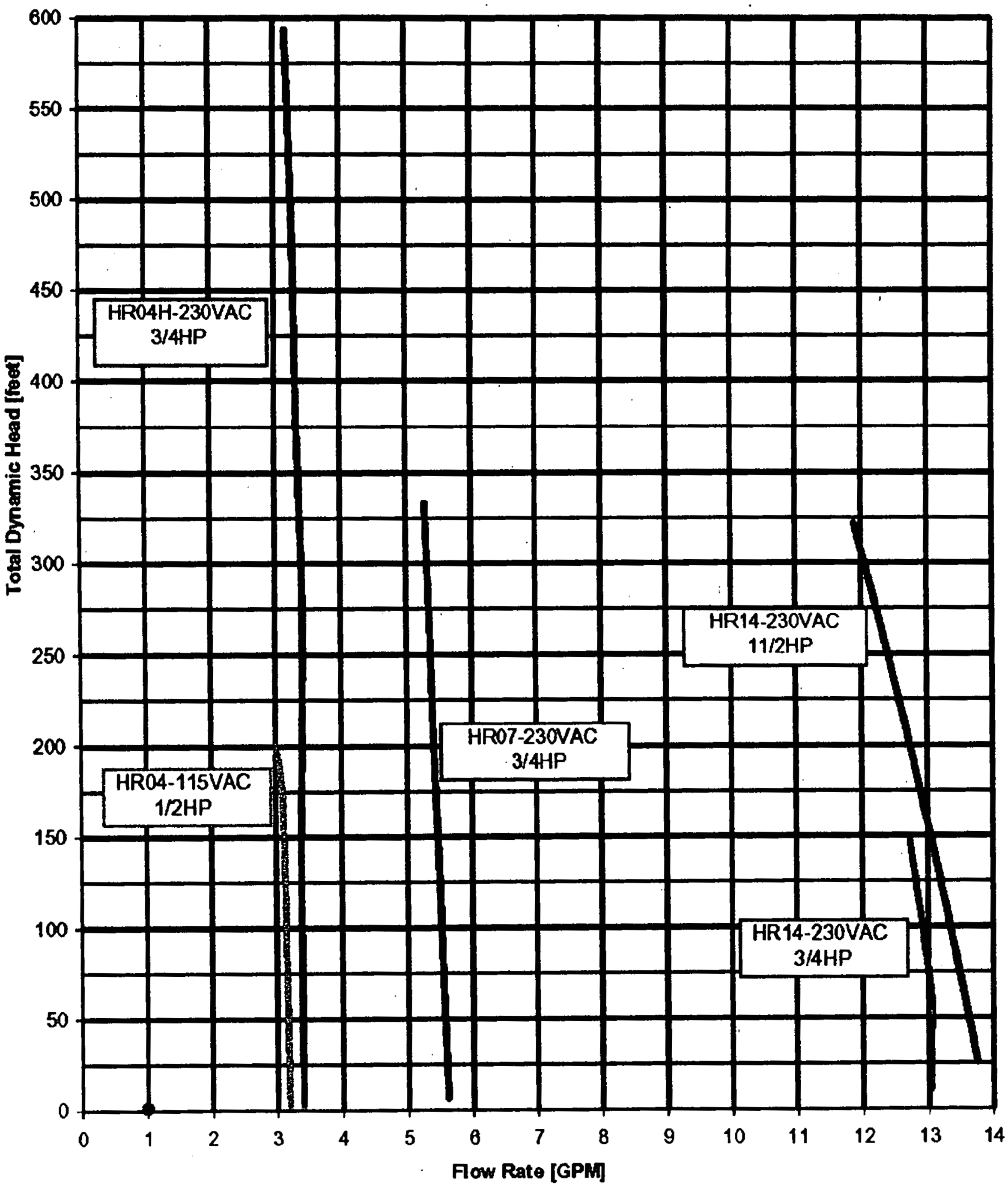
**MANUFACTURER'S WARRANTY**
1 YEAR against defects in materials and workmanship



LEFT TO RIGHT: helical rotor housing, helical rotor, motor, capacitor-start control box

# Helical Rotor Submersible
## ETAPUMP® HR
### 115VAC and 230VAC, 60 Hz

Dankoff Solar

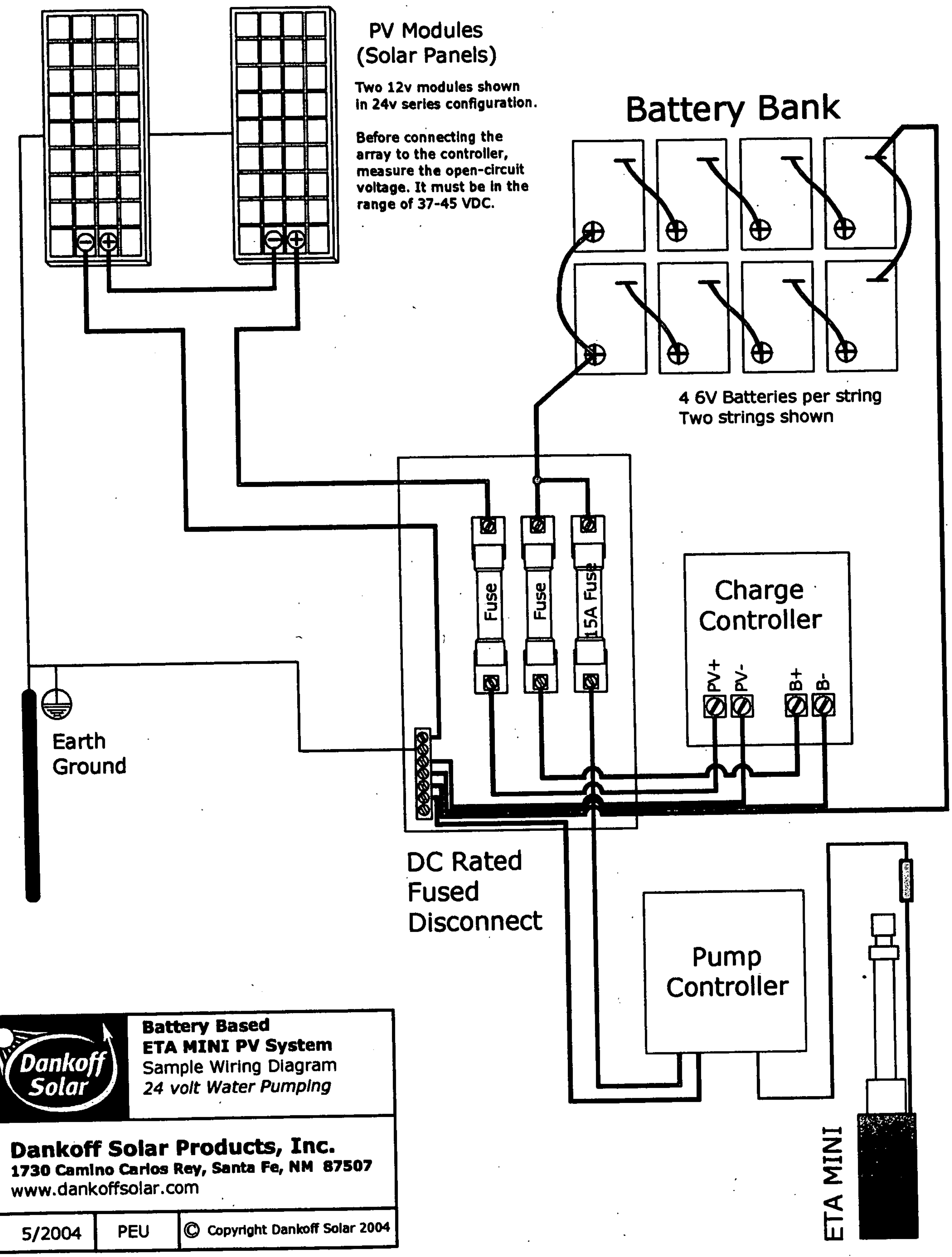



Dankoff Solar Products, Inc. Santa Fe, NM USA (505) 473-3800 (888) 396-6611
pumps@dankoffsolar.com www.dankoffsolar.com Version: Oct. 2002

125

# B.8 Battery Based ETA Mini PV System Sample Wiring Diagram

126




| | |
|---|---|
| Dankoff Solar | **Battery Based**<br>**ETA MINI PV System**<br>Sample Wiring Diagram<br>*24 volt Water Pumping* |

**Dankoff Solar Products, Inc.**
**1730 Camino Carlos Rey, Santa Fe, NM 87507**
www.dankoffsolar.com

| | | |
|---|---|---|
| 5/2004 | PEU |  |

# B.9 Concorde Sun Xtender® Battery Service Instructions

BATTERY SERVICE INSTRUCTIONS

3 1 2 ACID SUN XTENDER® SERIES ®
...the heart of your solar system

## MAINTENANCE-FREE, VALVE-REGULATED, SEALED LEAD-ACID BATTERIES DESIGNED FOR DEEP CYCLE / BACK-UP POWER PHOTOVOLTAIC APPLICATIONS

## BATTERY SERVICE INSTRUCTIONS

1. **CHARGE PROCEDURES** -

Concorde Sun-Xtender Sealed, Valve Regulated AGM Batteries are charged at the factory and are ready for installation when they are received. While in storage they should be boost charged every 90 days or when their open circuit voltage falls below 12.5 V for a 12 volt battery, 6.25 V for a 6 volt battery and 2.08 V for a 2 volt battery.

Boost charge batteries using a regulated constant potential [constant voltage] charger, with an output of 14.1 to 14.4 V [for 12 volt batteries]. The battery is considered fully charged when the current drops to approximately 0.5 A for one hour.

Batteries that have not been boost charged and have been in storage for long periods of time [not more than 9 months] may need a conditioning charge. These batteries should be charged at the constant current rate [listed below] until the voltage remains constant or decreases for one hour or until the battery temperature reaches 115 F [46 C] while on charge.

| CONSTANT CURRENT CHARGE RATE TABLE | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 VOLT BATTERIES | | | 6 VOLT BATTERIES | | | 2 VOLT BATTERIES | |
| PVX-340T | 2 | | PVX-1380T | 7 | | PVX-4140T | 19 |
| PVX-420T | 2 | | PVX-1680T | 8 | | PVX-5040T | 24 |
| PVX-490T | 2 | | PVX-1780T | 8 | | PVX-5340T | 24 |
| PVX-560T | 3 | | PVX-2080T | 10 | | PVX-6240T | 30 |
| PVX-690T | 3 | | PVX-2160T | 10 | | PVX-6480T | 30 |
| PVX-840T | 4 | | PVX-2240L | 11 | | | |
| PVX-890T | 4 | | | | | | |
| PVX-1040T | 5 | | | | | | |
| PVX-1080T | 5 | | | | | | |
| PVX-2120L | 10 | | | | | | |
| PVX-2580L | 12 | | | | | | |

2. **RESERVE CAPACITY TEST PROCEDURE** -

Make sure the battery is charged in accordance with paragraph 2 above.

With the battery temperature above 68 F [20 C] discharge the battery at 25 A to 10.5 V for a 12 V battery [1.75 V per cell]. Record the minutes of discharge.

If the battery fails to deliver 80% of its rated discharge time [in minutes] the battery should be replaced. Refer to the 25 A discharge time table below.

| 25 A DISCHARGE TIME TABLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 12 VOLT BATTERIES | | | | 6 VOLT BATTERIES | | | | 2 VOLT BATTERIES | | |
| | Rated | 80% | | | Rated | 80% | | | Rated | 80% |
| PVX-340T | 50 | 40 | | PVX-1380T | 242 | 194 | | PVX-4140T | 726 | 581 |
| PVX-420T | 61 | 49 | | PVX-1680T | 298 | 238 | | PVX-5040T | 894 | 715 |
| PVX-490T | 84 | 67 | | PVX-1780T | 316 | 253 | | PVX-5340T | 948 | 758 |
| PVX-560T | 96 | 77 | | PVX-2080T | 372 | 298 | | PVX-6240T | 1116 | 893 |
| PVX-690T | 121 | 97 | | PVX-2160T | 390 | 312 | | PVX-6480T | 1170 | 936 |
| PVX-840T | 149 | 119 | | PVX-2240L | 492 | 394 | | | | |
| PVX-890T | 158 | 126 | | | | | | | | |
| PVX-1040T | 186 | 149 | | | | | | | | |
| PVX-1080T | 195 | 156 | | | | | | | | |
| PVX-2120L | 390 | 312 | | | | | | | | |
| PVX-2580L | 504 | 403 | | | | | | | | |

All specifications and ratings subject to change without notice.

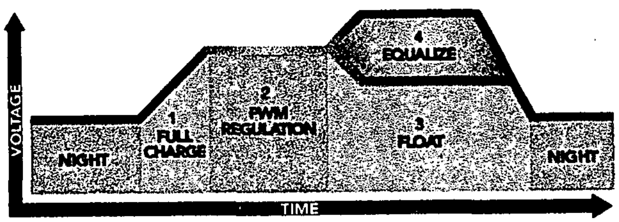
# PROSTAR™ TECHNICAL SPECIFICATIONS

## ProStar Options:

- Digital meter
  - Highly accurate voltage and current display
  - Low self-consumption (1 mA)
  - Includes manual disconnect button
  - Displays 5 different protection functions and disconnect conditions
  - Self-diagnostics (self-test) provides a comprehensive test of the ProStar —
    - Displays 9 different controller status parameters, including temperature
    - Displays detected faults
- Positive ground
- Remote temperature probe

## Optimized Battery Charging:

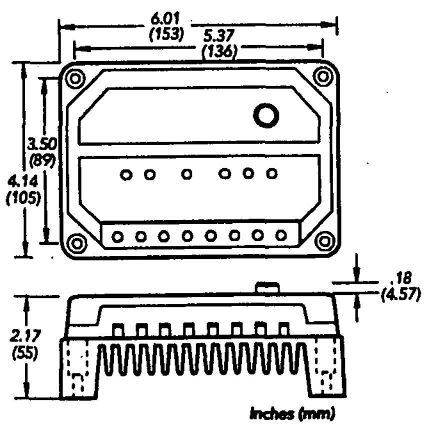
The ProStar has 4 stages of charging to provide increased battery capacity and life.




## Mechanical Specifications:

Weight:
12 oz
(0.34 kg)

Wire Size:
#6 AWG
(16 mm²)




## ProStar Versions:

| | PS-15 | PS-30 | PS15M-48V |
|---|---|---|---|
| Rated Solar Current | 15A | 30A | 15A |
| Rated Load Current | 15A | 30A | 15A |
| System Voltage | 12/24V | 12/24V | 48V |
| Options: | | | |
| Digital Meter | yes | yes | standard |
| Positive Ground | no | yes | yes |
| Remote Temp. Probe | yes | yes | yes |

## Battery Voltage Setpoints*

| | Gel | Sealed | Flooded |
|---|---|---|---|
| Regulation Voltage | 14.0 | 14.15 | 14.4 |
| Float | 13.7 | 13.7 | 13.7 |
| Equalization | n/a | 14.35 | 14.9/15.1 |
| Load Disconnect | 11.4 | 11.4 | 11.4 |
| Load Reconnect | 12.6 | 12.6 | 12.6 |

Note: values are for 12V. Use 2X for 24V and 4X for 48V.

## Electrical Specifications:

| | 12V | 24V | 48V |
|---|---|---|---|
| Temp. Comp. (mV/°C)* | – 30mV | – 60mV | – 120mV |
| Accuracy | 40mV | 60mV | 80mV |
| Min. voltage to operate | 8V | 8V | 15V |
| Self-consumption | 22mA | 25mA | 28mA |
| LVD current coefficient** | – 20mV | – 40mV | – 80mV |
| Charge algorithm | PWM, constant voltage | | |
| Operating temperature | – 40°C to + 60°C | | |
| Digital Display: | | | |
| Operating temperature | – 30°C to + 85°C | | |
| Voltage accuracy | 0.5% | | |
| Current accuracy | 2.0% | | |
| Self-consumption | 1 mA | | |

* 25°C reference
** per amp of load

**WARRANTY:** ***Five year warranty period. Contact Morningstar or your authorized distributor for complete terms.***

***AUTHORIZED MORNINGSTAR DISTRIBUTOR:***


MORNINGSTAR corporation
***1098 Washington Crossing Road***
***Washington Crossing, PA 18977 USA***
***Tel: 215-321-4457 Fax: 215-321-4458***
***E-mail: info@morningstarcorp.com***
***Website: www.morningstarcorp.com***


PRINTED IN USA 211E-R1-7/01

CE

## 7.3 Hand Installation

See PHOTO GALLERY for a picture of a hand installation.

Water well pumps can be installed by hand in shallow water sources and in remote areas that are not accessible to a pump service truck. Hand installation is generally performed using rolled flexible POLYETHYLENE (PE) drop pipe rather than rigid pipe. In North America, most professional pump contractors do NOT have the equipment to pull flexible pipe. Their equipment is designed for rigid pipe in 21-foot pieces. Do not use flexible pipe unless you are committed to safely handling its total weight (full of water) IN THE FUTURE when the pump must be removed. For installations that are deeper than about 50 feet (15m), please consider the following warnings and cautions.

**WARNING Hand installation and removal is potentially hazardous.**
We do not encourage hand installation except in shallow-water situations. Installation and removal should never be performed by hand without an adequate number of workers. If you have any doubts about the feasibility, safety and economy of installation AND future removal, hire a professional pump service contractor.

Before considering installation or removal by hand, estimate the weight of the system and consider the number of people necessary to install the pump AND to remove it in the future (with water in the pipe). To estimate the total weight, add the following:

1. Cable weight — #10 submersible cable (3-wire + ground) weighs approximately 25 lbs. per 100 ft. (40 kg per 100m). Each larger size (smaller AWG#) weighs approximately 30% more.
2. Water in the pipe (lbs.) = pipe inside diameter (inches)$^2$ X 0.34 X length (feet). Example: Water in 100 feet of 1" pipe weighs about 34 lbs.
3. The pump weighs approximately 25 lbs. (11.5 kg.).

**CAUTIONS for polyethylene pipe (PE, rolled pipe)**

1. Do not exceed the pressure rating of the pipe. The most common PE pipe is type SIDR-15. It has a pressure rating of 100 PSI (7 bar). This is equal to 230 feet (70m) of total vertical lift. Types SDR-9 and SIDR-7 have a pressure rating of 200 PSI (14 bar), equal to 460 feet (140m). They is available from local suppliers in some areas, or from your Dankoff Solar pump supplier. Special compression connectors are made for this pipe.
2. Use only pipe connectors that are designed for the pipe you choose. Do not use galvanized steel adapters. They will rust through.
3. Do not use any sealing compound in PE pipe connections.
4. If you use insert connectors with hose clamps, use TWO clamps at each adapter. Tighten them with a wrench. Use "all stainless" hose clamps. Automotive clamps have carbon steel screws that will rust and fail.
5. Have extra hose clamps on hand in case you damage or lose one.
6. Have an extra coupling on hand in case you bend the pipe too sharply (kink it) and make a weak spot.
7. PE pipe will stretch about 1%. Make the electrical cable and safety rope about 1.5% longer than the pipe so when the pipe stretches, the cable and splice will not be stressed.
8. If you plan to bury PE pipe in the ground, contact the pipe manufacturer for additional instructions.

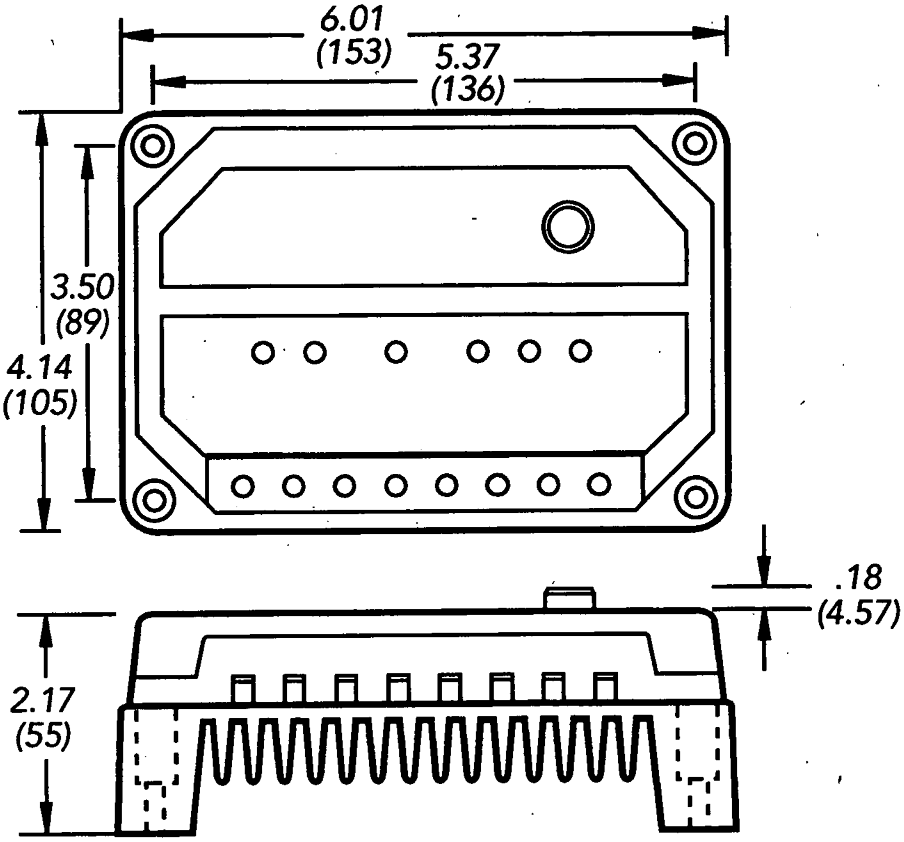
**WARNING DO NOT USE A ROPE WINCH to install or remove a pump in a drilled well casing (borehole).**
If you use a winch to pull the pump by winding up rope or wire rope, the electrical cable can slip down the pipe and/or the pipe can collapse. If the pipe or cable jams and gets wedged in the casing, you can lose your equipment and even permanently block the well! Some installers use a winch with a reel of about 3 feet (1m) diameter or larger, to pull flexible pipe. This is ideal if you have the equipment and experience to do the job safely.

**WARNING DO NOT USE A VEHICLE to install or remove a pump.** During removal, the pump can catch on joints or edges in the well casing. Damage or loss of the pump can occur before the vehicle operator can react.

## 7.4 Sanitizing the Well

Sanitizing a well will kill bacteria that may have been introduced during the pump installation. This can be done with chlorine bleach or chlorine pellets poured down the well just before or just after a pump is installed. Consult a local supplier or environmental health authority for a recommended procedure. *ETAPUMP* will not be damaged by normal quantities of chorine compound.

## *PROSTAR DIMENSIONS*




***inches (mm)***

# CONTENTS

## 1.0 GENERAL INFORMATION

Thank you for selecting the ProStar solar controller. This second generation ProStar adds new features and protections using highly advanced technology. Morningstar's patented PWM battery charging algorithm has also been further optimized for longer battery life and improved system performance.

Many functions of the ProStar are unique. Although the ProStar is very simple to use, please take the time to read this operator's manual and become familiar with the controller. This will help you to make full use of the many advantages the ProStar can provide for your solar system.

## 2.0 IMPORTANT SAFETY INFORMATION

***"Always Put Safety First"***

- Be very careful when working with batteries. Wear eye protection. Have fresh water available to wash and clean any contact with battery acid.
- Charge only lead-acid batteries that are properly sized for the system.
- Explosive battery gasses can be present during charging. Be certain there is enough ventilation to release the gasses.
- Use insulated tools and avoid metal objects near the batteries.
- Carefully read the battery manuals and other equipment manuals before installing the solar system. Observe ALL precautions when working with batteries and power electronics.
- Fuses or DC disconnects may be required in the system. These protective devices are not part of the ProStar controller.
- Avoid large voltage drops in the battery wires. Use the Battery Sense connection for best battery charging and system performance.
- Do not allow water to enter the controller.
- Avoid touching the controller heat sink. Under certain operating conditions, the heat sink can become hot.
- Install the controller in a vertical position with adequate space for ventilation.
- Ensure that the system is properly grounded.
- SAVE these instructions for future reference.

## 3.0 QUICK START INSTRUCTIONS

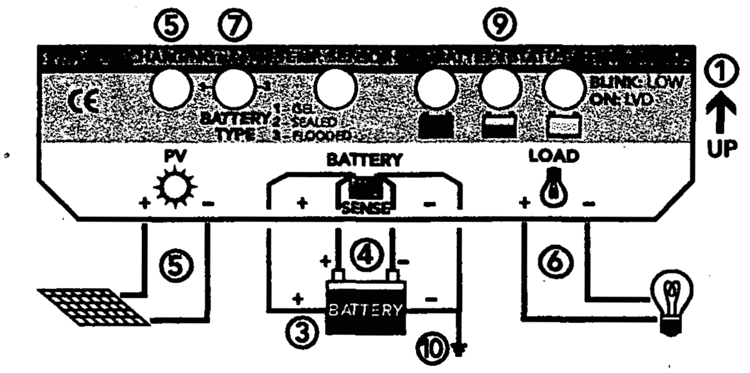
This section provides a brief overview of how to get started using the ProStar controller. However, please review the entire manual to ensure best performance and years of trouble-free service.

1. Mount the ProStar to a vertical surface. Allow space above and below the controller for air flow. The heat sink MUST be in a vertical (up & down) position.
2. Make sure the Solar and Load currents will not exceed the ratings of the ProStar version being installed.



137

3. Connect the **Battery** first. Observe that the Battery Status LEDs blink in sequence one time. Torque all the ProStar terminals tightly, but do not exceed 35 in-ib.
4. Connect the battery **Sense**. This is recommended, but not required, if the battery is located more than 5 meters from the controller.
5. Connect the **Solar**. With sunlight, the green **Charging** LED will light.
6. Connect the **Load**. If there is a fault, the LEDs will begin blinking. Refer to section 4.0 of this manual to identify the fault.




7. Select the proper charging for the battery being used. Turn the rotary switch with a screwdriver to the **Battery Type** printed on the label. The Battery Status LEDs will blink 1, 2 or 3 times depending on the Battery Type selected.
8. For 12 or 24 volt systems, the ProStar will automatically select the system voltage. If the system is 24 volts, first confirm that the battery is above 15.5 volts. The controller selects 12 or 24 volts at start-up.
9. Observe the LEDs and digital meter (if provided) to confirm normal operation.
10. It is recommended that the system be properly grounded.

## 4.0 LED INDICATORS

The 4 LEDs in the lower label indicate system status and various faults. These functions are described below.

***CHARGING*** (LED 1 – green)

**ON:** battery charging during sunlight (always on during sunlight)

**OFF:** normal during night (off during sunlight indicates solar reverse polarity or overcurrent)

***BATTERY STATUS*** (LEDs 2 – 4)

**GREEN:** **ON** indicates battery is near full charge
**BLINKING** indicates PWM charging (regulation)

**YELLOW:** **ON** indicates battery at middle capacity

**RED:** **BLINKING** indicates a low charge state and a low voltage load disconnect (LVD) warning
**ON** indicates the load has been disconnected (LVD)

***FAULT INDICATIONS*** (G = green; Y = yellow; R = red)

| | |
|---|---|
| **G/Y/R blinking together** | – battery select fault |
| **R – Y sequencing** | – high temperature disconnect |
| **R – G sequencing** | – high voltage disconnect |
| **R/G – Y sequencing** | – load short circuit or overload |

## *5.0 DIGITAL METER & MANUAL DISCONNECT*

A digital meter is available with the ProStar controller as an option. If your version includes the meter display, this section will describe the information that can be displayed with the meter, and the added capabilities that are enabled by the push button switch.

### *5.1 DIGITAL METER*

A precision 3-digit digital meter will continuously display battery voltage, solar current, and the load current. The meter automatically scrolls through these 3 displays. The 3 red LEDs will indicate which parameter is being displayed.

The digital meter will operate from –30°C to +85°C. The values displayed are calibrated electronically in production and are accurate to within a few percent. Please note, however, that if the Battery Sense is not connected, the voltage displayed will be in error by the voltage drops in the battery wires.

### *5.2 MANUAL DISCONNECT*

The push button next to the digital display can disconnect the Load or both Load and Solar. A second push of the button will return the controller back to normal operation.

> **LOAD OFF:** A brief push of the button (less than 2 seconds) will disconnect the Load. The Solar remains on and charging.
>
> **LOAD AND SOLAR OFF:** If the button is held down for 2 seconds, the Solar will also be disconnected.

When the button is pushed, the red LED inside the cap will light. In addition, the Load or both Load and Solar will display "OFF" in the digital meter to indicate the disconnected state.

### *5.3 DISPLAY DISCONNECTS & PROTECTIONS*

The following protection functions and disconnect conditions will be displayed in the digital meter when they occur:

| | |
|---|---|
| *Lud* | LVD – low voltage load disconnect (load only) |
| *Hud* | high voltage disconnect (both solar and load) |
| *Hot* | high temperature disconnect (both solar and load) |
| *OCP* | overcurrent and short circuit protection (load, solar overcurrent) |
| *0.0* | short circuit protection (solar only) |

### *5.4 SELF-DIAGNOSTICS (SELF-TEST)*

If the push button is held down for 4 seconds, the ProStar will go into automatic self-diagnostics. Note that the button must be released to start the self-test.



139

**NOTE:** The push button can be used to toggle through the displays faster. The entire self-test takes 30 to 45 seconds. The load will be turned on for 0.1 second and may flash during the test. A short or overload condition could cause a controller restart.

***The following displays will occur (examples are used):***

| | |
|---|---|
| 8.8.8 | self-test started, checking the digital meter segments |
| 12u | the system voltage (12/24/48) |
| 15A | ProStar current rating |
| r 1.5 | software version installed |
| E04 | a fault has been detected (see list below) |
| --- | display if no fault is found |
| 25c | temperature measured at the controller |
| rP | remote temp probe is detected (if connected) |
| 25c | temperature at the remote probe (if connected) |
| SEn | battery sense detected (if connected) |
| S-1 | battery select position (1,2, or 3) |
| J-1 | telecom noise jumper cut (change to on-off regulation) |
| End | end of the self-test |
| End---End | display continues if no error was detected. |
| End End | display continues if an error has been detected. |

***To terminate the self-test, push the button.***
***The self-test can be repeated to confirm the result.***

***Error List:***

| | |
|---|---|
| E01 | Rotary switch battery selection failure |
| E03 | Voltage reference test failed (circuit, malfunctions) |
| E04 | Solar array current fault (circuit, FETs) |
| E07 | Load FETs off test (load connection, FETs shorted) |
| E08 | Load current fault (circuit, FETs) |
| E09 | Load FETs on test (load circuit, FETs open) |
| E10 | Internal temp sensor out of range high |
| E11 | Internal temp sensor out of range low |
| E12 | Remote temp probe out of range |
| E13 | Battery sense fault (battery V drop over 5V, no Sense negative connection) |

**NOTE:** In addition to the self-test, observe the solar and load currents displayed in the meter. The self-diagnostics plus the currents displayed in the meter will provide a comprehensive test of the ProStar. Some faults may exist that are not detected by the self-test, but the large majority of potential faults will be tested and reported in this self-diagnostic test.

***Refer to section 9.0 for more information.***



140

# 6.0 INSTALLATION INSTRUCTIONS

The ProStar is installed in 10 steps. Follow the procedure in section 6.2 for a proper installation and best performance.

## 6.1 GENERAL INSTALLATION NOTES

- The ProStar uses stainless steel fasteners, an anodized heat sink, and conformal coating to protect from harsh conditions. However, for acceptable service life extreme temperatures and marine environments should be avoided.
- The ProStar prevents reverse current leakage at night, so a blocking diode is not required in the system.
- The ProStar is designed to regulate ONLY solar (photovoltaic) power. Do not connect it to any other type of power generator. Do not attempt to regulate a wind turbine. However, other power sources can be connected directly to the battery.
- The connector terminals will accept a maximum wire size of AWG #6 / 16 mm2 (solid/multistrand) or AWG #8 / 10 mm2 (fine strand). Use a flathead insulated screwdriver, and torque tightly up to 35 in-lb.
- Fuses or DC disconnects may be required in the system. These protection devices are not part of the ProStar controller.

> ***NOTE:*** *Carefully observe the LEDs at each connection. The LEDs will indicate proper polarity and a good connection.*

## 6.2 INSTALLATION STEPS

Refer to the wiring connection diagram in section 3.0.

### *STEP 1: Mounting*

Inspect the controller for shipping damage. Mount the ProStar to a vertical surface (4 stainless steel #8 self-tapping screws are included). Tighten the mounting screws using care not to crack the plastic case. Do not install directly over an easily combustible surface since the heat sink may get hot under certain operating conditions.

> ***NOTE:*** *Heat sink must be in a vertical position (fins up and down).*

Allow at least 15 cm (6 inches) space above and below the controller for air flow. Install in an area protected from direct rain and direct sun.

If the controller is installed in an enclosure, some ventilation is recommended. Do not locate in an enclosure where battery gasses can accumulate.

### *STEP 2: Ratings*

Confirm that the solar array and loads will not exceed the current rating of the ProStar version being installed.

Multiple ProStar units can be paralleled at the system battery to increase the solar capacity, but do not parallel loads.



141

**NOTE:** *The battery should be connected first. This will activate the controller protection features, and will power the LEDs to guide installation and start-up.*

***STEP 3: Battery***

Before connecting the battery, measure the battery's open-circuit voltage. It must be over 8 volts to operate the controller. For 24 volt systems, the battery must be over 15.5 volts or the ProStar will regulate for 12V. The 12/24V auto selection is only done at start-up.

Connect the battery and confirm that the 3 Battery Status LEDs blink in sequence. If they do not light, check the battery polarity (+/–) and battery voltage.

**CAUTION:** *The ProStar is protected against all faults EXCEPT a reversed battery connection together with a polarized or short circuited load. CONFIRM that the battery + and – wires are correctly connected before proceeding. Check the wires and the LEDs.*

The green, yellow or red LED will light depending on the battery charge state. Confirm one of these LEDs is on before going to the next step.

***STEP 4: Sense***

Battery sense connections are recommended if the controller is more than 5 meters from the battery. The Sense, connected directly to the battery, will improve the battery charging and control.

Both Sense wires (+/–) must be connected. A small wire size (18 AWG or larger) can be used for the Sense because the current is very low. Note that the middle 2 terminals are for sense (with the smaller wire slots in the case).

**NOTE:** *If the Battery input voltage is more than 5 volts different than the Sense due to voltage drops or faulty connections, the Sense input will not be recognized by the ProStar.*

***STEP 5: Solar***

These terminals are used to connect the Solar (PV) array. First confirm that the solar modules are wired for the same voltage as the battery.

Use caution, since the solar array will produce power whenever in sunlight. If the solar is connected while in sunlight, the Charging LED indicator will light. Confirm proper connection with the Charging LED.

***STEP 6: Load***

Turn the load off, and connect the load wires to the Load terminals. Turn the load on to confirm a proper connection.

If the load does not turn on, it could be for various reasons:

- the ProStar is in LVD (red LED on)
- there is a short circuit in the load (LEDs blinking R/G – Y)
- there is an overload condition (LEDs blinking R/G – Y)
- the load is not connected, not working, or turned off

***Confirm the load is working properly before going to Step 7.***

***STEP 7: Battery Type Selection***

Using a small screwdriver, turn the rotary switch to select the Battery Type. There are 3 choices (see section 8.2):

1 = Gel battery

2 = Sealed battery

3 = Flooded battery

A proper selection will flash the 3 Status LEDs together: 1 time for Gel, 2 times for Sealed, and 3 times for Flooded.

If the rotary switch does not make a good contact with one of the 3 selections, the 3 LEDs will start flashing together and continue until a good contact is made.

***STEP 8: Confirm Installation***

After the connections are completed, observe the LEDs to make sure the controller is operating normally for system conditions. If the optional digital meter is provided, observe that the display is scrolling with proper voltage and amperage values. A self-test can be performed with the digital meter (see section 5.4).

***STEP 9: Grounding***

For safety and effective lightning protection, the negative conductor of the solar system should be properly grounded (see the NOTE below). In addition, the heat sink can be grounded with a #8-32 UNC or M4 screw (0.136 hole provided).

The Solar, Battery, and Load negative terminals are all connected together inside the ProStar per UL recommendations. No switching or measurement is done in the negative current path.

**NOTE:** *For positive ground versions, the Solar, Battery and Load POSITIVE terminals are connected together inside the ProStar. The positive system conductor must be properly grounded. Make sure the upper label of the ProStar indicates "Positive Ground" above the version number to confirm this is a positive ground ProStar controller.*

# 7.0 OPERATION

## 7.1 OPERATOR'S TASKS

The ProStar is a fully automatic solar system controller that includes many electronic functions to protect both the controller and the solar system. Battery charging is also fully automated (see section 8.0).

***The only manual tasks performed by the operator are:***

a. Installation (see section 6.2)

b. Battery type selection (see section 6.2, Step 7)

c. Disconnect button / Self-test (see section 5.2 and 5.4)

d. Reset if a load short circuit does not automatically clear (see section 7.3)

e. Maintenance (see section 7.4)

### 7.2 OPERATIONS & FUNCTIONS

The solar system operator should become familiar with the following operating functions of the ProStar controller. Refer to the Technical Specifications (section 10.0) for actual setpoints and other parameter values.

- **100% Solid State:** All power switching is done with FETs. No mechanical relays are used in the controller.
- **Battery Charge Regulation:** The ProStar is a PWM battery charger. See the next section (8.0) for a description of battery charging.
- **Low Voltage Load Disconnect (LVD):** An automatic load disconnect protects the battery from deep discharge. The load automatically reconnects when the battery recovers. A 4-minute delay prevents false LVD disconnects.
- **Low Voltage Warning:** The red status LED will blink at low battery capacity to warn of a possible LVD.
- **Parallel Controllers:** ProStar controllers work very well in parallel configurations. No blocking diodes are required. Each controller must have an independent and separate solar subarray and a load that does not exceed the controller's rating.
- **Auxiliary Generators:** Engine generators and other sources of power may be connected directly to the battery for charging. It is not necessary to disconnect the ProStar from the battery. However, do not use the ProStar to regulate these other sources of power.

***Noise:*** *The ProStar circuit minimizes switching noise and filters noise output. A properly grounded system will also minimize noise. If noise is present in a telecom or radio load, refer to section 7.5 below.*

### 7.3 PROTECTIONS

The ProStar is fully protected against system faults listed below. Recovery is automatic except where noted below. Refer to sections 4.0 and 5.0 for fault indications.

- Solar short circuit and overload – fully automatic recovery
- Load short circuit and overload – after 3 automatic load reconnect attempts (10 seconds between each attempt), the fault must be cleared and the load must be turned off or disconnected for 10 seconds or longer to restore power to the load terminals.
- Reverse polarity – fully protected except per Caution below
- Battery disconnected – the load is protected from voltage spikes
- High temperature – first the solar is disconnected, then the load will be disconnected; auto reconnects
- High battery voltage – first the solar is disconnected, then the load will be disconnected; auto reconnects
- Very low battery voltage – brownout protection, auto recovery into LVD state
- Battery select error – defaults to gel battery setting, flashes LEDs
- Temperature sensor failure – a remote probe failure defaults to the internal temperature sensor, which defaults to a fixed 25°C if it fails

***CAUTION:*** *One source of potential damage to the controller is a reversed battery polarity (+/–) together with a polarized or short-circuited load.*



144

## 7.4 INSPECTION & MAINTENANCE

The following inspections and maintenance tasks are recommended at least two times per year for best controller performance.

1. Confirm that the correct battery type is selected. Turn the rotary switch to another setting and then back to the setting desired, and count the LED flashes.
2. Confirm that the maximum current of the solar array and load does not exceed the ProStar ratings.
3. Tighten all the terminals. Inspect for loose or broken wire connections.
4. Check that the controller is securely mounted in a clean, protected environment.
5. Check that the air flow and the ventilation holes are not blocked.
6. Inspect for dirt, insects, nests, and corrosion.
7. Check that the controller functions and LED indicators are correct for the system conditions at that time.

## 7.5 SPECIAL FEATURES

Two specialized capabilities will apply to some ProStar owners.

### A) Remote Temperature Probe

An optional remote temperature probe can be soldered to the ProStar assembly at any time. The standard cable length is 25 ft (7.6 m), and this can easily be extended to 100 ft (30 m) or longer. The 2 probe wires are soldered to the main board assembly between the temperature sensor and the green LED, at "J12".

Instructions are provided with the remote probe. The ProStar will automatically select the remote probe for battery temperature compensation if it is installed.

### B) Telecom Noise Jumper

Some telecom equipment will produce noise when the ProStar begins PWM regulation. If this occurs, a jumper can be cut to eliminate the noise. Instructions follow:

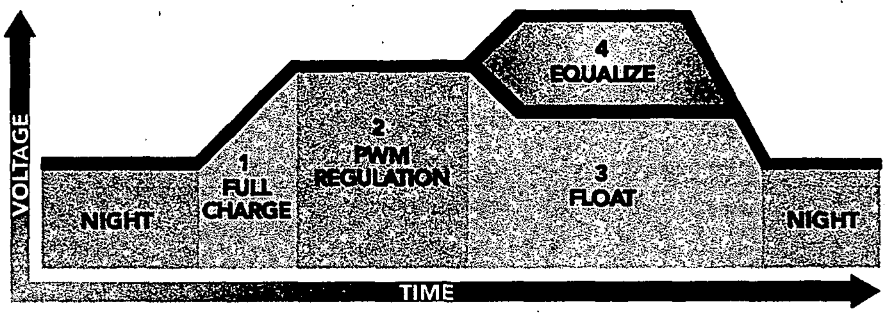
- First, try to improve the system grounding which often eliminates the noise. The PWM battery charging provides a significant benefit to the battery, and it is worth trying to preserve the PWM charging.
- If the noise continues, disconnect the controller and remove the ProStar assembly from its plastic case.
- Locate a vertical resistor in the upper right hand corner of the board, near the microcontroller. This is identified as "J11" on the board.
- Cut one leg of the resistor and separate the leads.

This will convert the battery charging to a typical "on-off" regulation of the solar energy. The switching is very slow, so the noise will not be noticeable. The equalization and float features of the battery charging algorithm are preserved in the "on-off" mode.

In the future, this can be reversed back to PWM if the cut jumper leg is soldered back together.

# 8.0 BATTERY CHARGING INFORMATION

The ProStar is an advanced, fully automatic solar battery charger. No adjustments are required except to select the battery type at installation (see section 8.2 below).




## 8.1 PROSTAR CHARGING METHOD

The ProStar uses 4 stages of charging for rapid, efficient and safe battery charging. These are shown in the diagram below:

1. Recharging with 100% of available solar energy.
2. PWM constant-voltage regulation to prevent heating and excessive battery gassing. Pulse charging to restore full battery capacity.
3. Float: After battery is fully recharged, ProStar reduces to a float or trickle charge. The transition depends on battery history. A load that exceeds available solar output will return ProStar to the PWM mode.
4. Equalize: A boost charge that depends on elapsed time and battery history. Flooded cells receive a vigorous equalization, sealed batteries a smaller boost to bring uneven cells into balance and extend the battery life. Gel cells are not equalized.

## 8.2 SELECT BATTERY TYPE

The Battery Type rotary switch allows selection of 1 of 3 charging algorithms. These are broadly defined as the following battery types as noted on the lower label:

1. **Gel:** Some gel and other battery types recommend lower regulation voltages and no equalization. This setting regulates to 14.0V (for a 12V battery).
2. **Sealed:** AGM, "maintenance free" and some types of gel batteries. Regulates to 14.15V (12V battery) with 14.35V boost charging.
3. **Flooded:** Vented cells that require water to be added. Regulates to 14.4V with 14.9V and 15.1V equalizations (12V battery).

***The above values are 2 times for 24V, and 4 times for 48V.***

***The battery type selection can be changed at any time.***

## 8.3 PROSTAR CHARGING FEATURES

Other ProStar capabilities for best battery life follow:

- **Night Disconnect:** The solar array automatically disconnects at night to prevent reverse current leakage from the battery.

- **Battery Sense:** Good battery performance requires accurate charging. Voltage drops in the battery power cables can distort the battery charging. The Sense wires eliminate the voltage drops for optimized charging.
- **Temperature Compensation:** Four control setpoints (25°C reference) are compensated for temperature (PWM regulation, float, equalization, high voltage disconnect). The charging is compensated by –5 mV/°C /cell (–30mV/°C for a 12V battery). Compensation is limited to minus 30°C.
- **Remote Temperature Probe:** An optional probe is available to measure temperature at a location away from the controller. This requires soldering 2 wires to the ProStar PCB. See section 7.5.
- **Battery Equalization:**

| | **Sealed** | **Flooded** |
|---|---|---|
| **Calendar – 25 days** | | |
| Equalization voltage | 14.35 | 14.9 |
| Cumulative time | 1 hour | 1 hour |
| Time starts above (V) | 14.3 | 14.6 |
| **Battery History** (flooded only) | | |
| Battery voltage falls below (V) | N/A | 11.7 |
| Equalize voltage | | 15.1 |
| Cumulative time | | 2 hours |
| Time starts above (V) | | 14.6 |
| Reset 25-day calendar | | yes |

***The above battery setpoints are 2 times for 24V, and 4 times for 48V.***

# 9.0 TESTING AND TROUBLESHOOTING

## 9.1 SELF-DIAGNOSTICS

If your ProStar includes the optional digital meter, refer to section 5.4 for how to perform a self-test of the ProStar. This will test for almost all failure modes of the ProStar and display any faults that are found.

If the self-diagnostic test indicates that no failures were found, it is very likely that the problem is with the solar system or battery.

## 9.2 TECHNICAL SUPPORT

Additional technical information and support can be found at Morningstar's Website:
**www.morningstarcorp.com**

## 9.3 TESTING WITH A POWER SUPPLY

The ProStar can be tested with a power supply used in place of either the solar array input or the battery. To avoid damage to the ProStar, observe the following cautions:

- Current limit the power supply to no more than half the ProStar rating.
- Set the power supply to 15 volts DC or less for 12V systems (30V for 24V systems and 60V for 48V systems).
- Connect only one power supply to the controller.

***Failure to follow these precautions may void the warranty.***

## 9.4 TROUBLESHOOTING

The ProStar is assembled with automated equipment, tested with computers, and is protected from faults. It is usually worthwhile to troubleshoot the entire solar system for faults, since the ProStar will generally not be the cause of a problem. Most problems will be caused by wiring connections, batteries unable to hold a charge, or faulty loads.

*CAUTIONS:*

1. Troubleshooting should be done by qualified personnel.
2. A battery can cause serious damage if shorted.
3. There are no user serviceable parts, fuses or circuit breakers inside the ProStar.
4. Observe all normal precautions when working with energized circuitry.

> **NOTE:** *If soldering is required, simply solder-through the conformal coating. The coating is acrylic and does not affect soldering.*

### 1. BATTERY IS NOT CHARGING

- Check the green CHARGING LED above the Solar input. With sunlight on the solar array, this LED should be on.
- Check that the proper BATTERY TYPE has been selected.
- Check that all wire connections in the system are correct and tight. Check the polarity (+/–) of the connections.
- Measure the solar array open-circuit voltage (disconnected from the controller) and confirm it is normal. If the array voltage is low or zero, repair the fault in the array.
- Confirm that the load is not drawing more energy than the solar array can provide.
- If the BATTERY SENSE terminals are not used, there may be excessive voltage drops between the ProStar and the battery. This is a common cause of undercharging batteries. See section 6.2 to connect the Battery Sense.
- Check the condition of the battery. Determine if the battery voltage falls at night with no load. If the battery is unable to maintain its voltage, it may be failing
- Measure the solar input voltage (during daytime) and battery voltage at the ProStar terminals. If the voltages at the terminals are the same (within about 0.5 volts), the solar array is charging the battery. If the solar voltage is close to open-circuit (about 20V), and the battery voltage is low, the controller is not charging the battery and may be defective. Make sure the ProStar is not in regulation (PWM) for this test (see section 4.0).

> **NOTE:** *If the battery is not being fully recharged, measure the voltage at the battery terminals on the ProStar, and then at the terminals on the battery. This should be done at midday with full charging from the solar array (and not in PWM regulation). If the ProStar terminals are 1 volt higher than the battery terminals, for example, this voltage drop will cause the battery to regulate 1 volt below its desired regulation (PWM) voltage, and it will take longer to recharge. In this case, the SENSE terminals should be connected to the battery for accurate charging.*

### 2. BATTERY VOLTAGE IS TOO HIGH

- First check the operating conditions to account for temperature compensation (a 15°C / 59°F temperature will increase PWM regulation by 0.3V for a 12V battery) and automatic equalizations.

- Check that the proper battery type has been selected.
- Disconnect the solar array, and remove the battery wire from the ProStar battery positive (+) terminal. Wait a few seconds and reconnect the battery positive terminal (leaving the solar array disconnected). After start-up, the green CHARGING LED should not be on. Measure the voltage at the SOLAR terminals (with the array still disconnected). If battery voltage is measured at the SOLAR terminals and the green LED is on, the controller may be defective.

> **CAUTION:** *If your ProStar is a positive ground version, references above to Battery (+) terminals should be Battery (–) negative terminals.*

### *3. LOAD IS NOT OPERATING PROPERLY*

- Check that the load is connected and turned on. Confirm that no fuses or circuit breakers in the system are tripped (there are no fuses or circuit breakers inside the ProStar).
- Check all connections to the load, and battery connections. Make sure voltage drops in the system are not too high (a voltage drop to the load will reduce the voltage at the load).
- Check the LED indications on the ProStar. If the red status LED is on, the load has been disconnected due to low battery voltage (LVD). This is a normal protection function of the ProStar, and the load will be automatically reconnected when the battery is charged by the solar array.
- If the LEDs are blinking, the load may have been disconnected for protection from one of the following faults:
  - short circuit or overload (R/G–Y sequencing)

> **NOTE:** *After 3 automatic retries, the fault must be cleared and the load must be switched off or disconnected for 10 seconds or longer to restore power to the load terminals*

  - high temperature (R–Y sequencing)
  - high voltage (R–G sequencing)

- Measure the voltage at the BATTERY terminals. If above LVD and no faults are present, the load should have power. Then measure the voltage at the LOAD terminals, and if there is no voltage present the controller may be defective.

> **NOTE:** *For more technical and testing information, visit Morningstar's Website:* **www.morningstarcorp.com**

# 10.0 TECHNICAL SPECIFICATIONS

**Note:** Values are for 12V versions. 24V versions are 2 times (48V are 4 times) the 12V values unless noted otherwise.

## ELECTRICAL

- **Accuracy**
  - 12V 40 mV
  - 24V 60 mV
  - 48V 80 mV
- **Min. voltage to operate**
  - 12/24V 8 V
  - 48 V 15 V
- **Self-consumption**
  - 12/24V 22 / 25 mA
  - 48V 28 mA
- **LVD current coefficient**
  - –20 mV/amp load
  - 24 V / 48 V –40 mV / –80 mV
- **High temp shutdown**
  - 70°C disconnect solar
  - 80°C disconnect load
  - 60°C reconnect load
  - 50°C reconnect solar
- **Voltage drops (max.)**
  - solar / battery 0.2 V
  - battery / load 0.12 V
- **Operating life**
  - 15 years
- **Transient surge protect**
  - pulse power rating 1500 watts
  - response < 5 nanosec

## METER DISPLAY

- **Type** LCD
- **Temp rating** –30 to +85°C
- **Voltage accuracy** 0.5%
- **Current accuracy** 2.0%
- **Self-consumption** 1 mA

## BATTERY STATUS LEDS

| | Falling V | Rising V | |
|---|---|---|---|
| G to Y | 12.1 | 13.1 | Y to G |
| Y to Blink R | 11.7 | 12.6 | Blink R to Y |
| Blink R to R | 11.4 | 12.6 | R to Y |

## BATTERY SETPOINTS (@ 25°C)

| | Gel | Sealed | Flooded |
|---|---|---|---|
| • **LVD** | 11.4 | 11.4 | 11.4 |
| • **LVD reconnect** | 12.6 | 12.6 | 12.6 |
| • **PWM regulation** | 14.0 | 14.15 | 14.4 |
| • **Float** | 13.7 | 13.7 | 13.7 |
| • **Equalization** | N/A | 14.35 | 14.9 / 15.1 |
| • **HVD (solar)** | 15.2 | 15.2 | 15.2 |
| • **HVD (load)** | 15.3 | 15.3 | 15.3 |

## BATTERY CHARGING

- **Charge algorithm** PWM, constant voltage
- **Temp comp. coefficient** –5mV/°C/cell (25°C ref)
- **Temp comp. range** –30°C to +80°C
- **Temp comp. setpoints** PWM, float, equalize, HVD
- **Equalization** see section 8.3

## MECHANICAL

- **Dimensions: (inch)** 6.01 x 4.14 x 2.17
  - 153 x 105 x 55
- **Weight** 12 oz (0.34 kg)
- **Wire terminals** Euro-style
  - solid #6 AWG / 16 mm2
  - multistrand #6 AWG / 16 mm2
  - fine strand #8 AWG / 10 mm2
- **Terminal diameter** 0.210 in / 5.4 mm
- **Torque terminals** up to 35 in-lb

## ENVIRONMENTAL

- **Ambient temperature** –40 to +60°C
- **Storage temperature** –55 to +85°C
- **Humidity** 100% (NC)

***Specifications subject to change without notice.***
***Designed in the U.S.A.***
***Assembled in Singapore.***

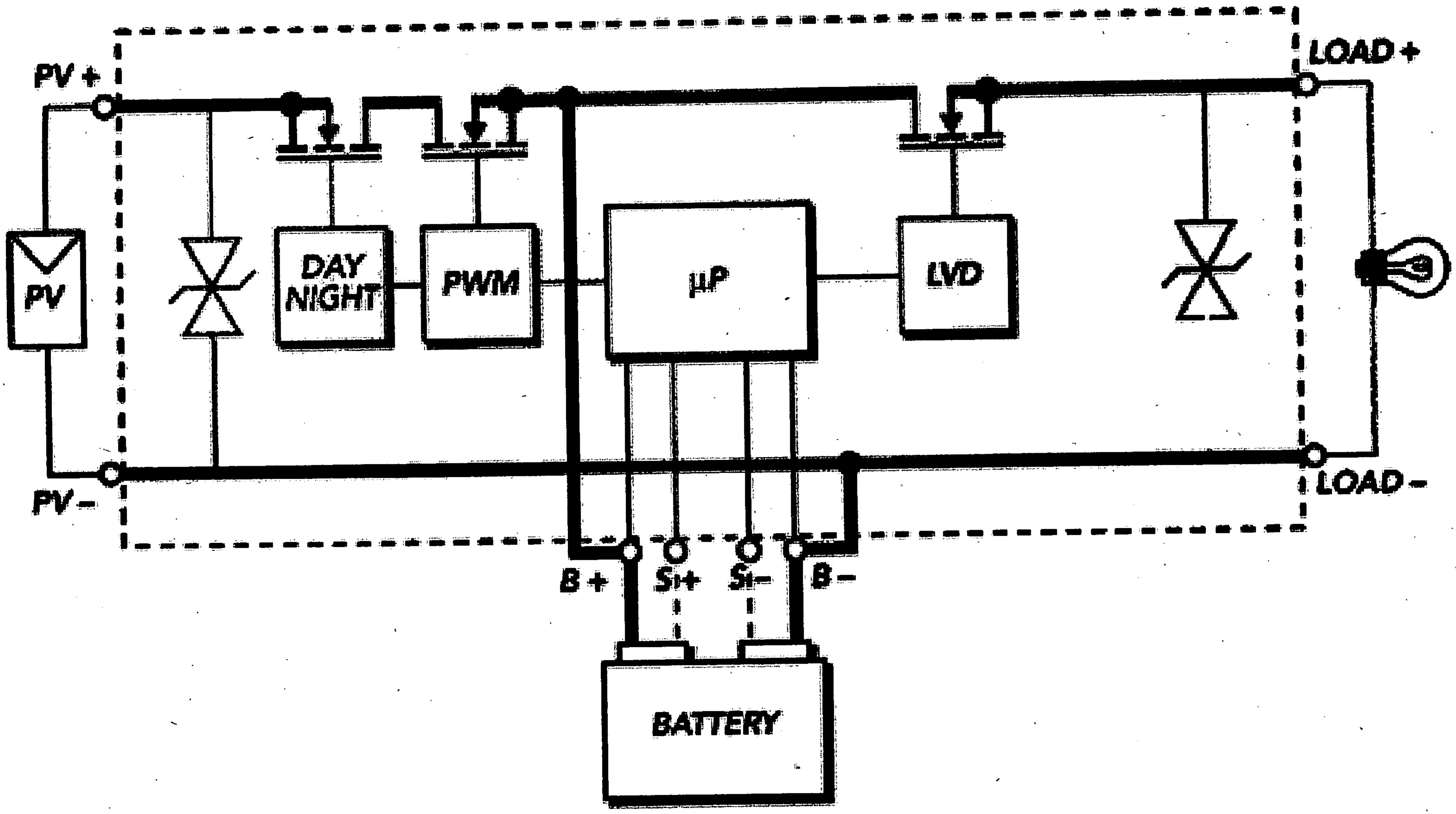
CE

***MS-ZMAN-PS01-A (April 01)***



150

151



# ProStar Bench Test Instructions

## Morningstar Corporation

## Last updated: 17 October 2001

## Tools:

Phillips screwdriver
Flat-blade screwdriver
DMM(digital multimeter)
Power supply, 20V 2A or similar
Small Ah 12V battery (~10Ah)
Small 12VDC load (eg. Small 1/3A bulb)

**NOTE: All equipment ratings and testing values are for 12/24V ProStars. Multiply all voltage ratings and values by 4 for 48V controllers**

## 1. Getting Started

A few things to do before we begin.

### Disconnect unit from system wiring

- Open disconnects, switch off breakers
- Be careful not to short or damage the controller when removing

### Inspect for physical damage to case, heatsink, or protruding components

### Remove cover (keep handy to reference terminal positions when wiring during testing)

- Flip the unit over (face down)
- Remove the 4 screws that secure the black heat sink to the plastic enclosure
- Carefully remove the plastic case

### Not necessary to remove external temperature probe if installed

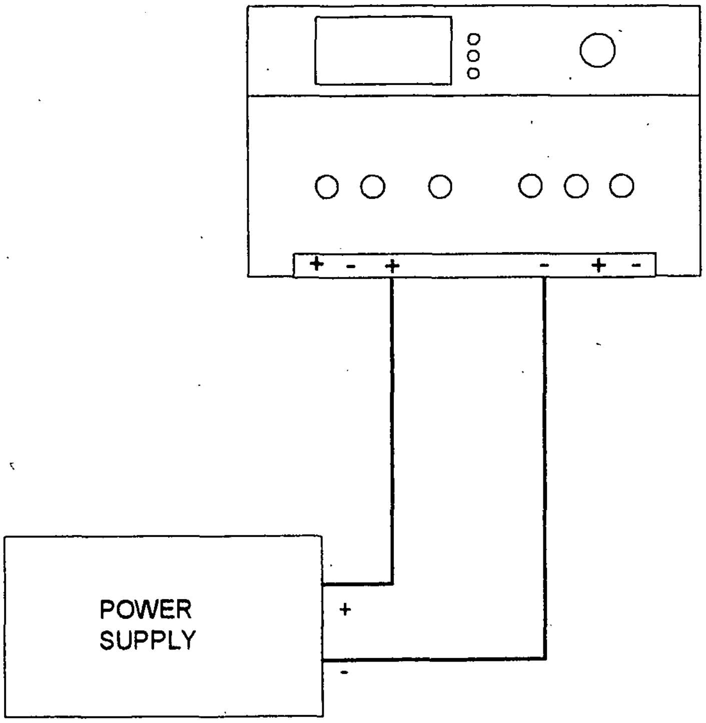
## 2. Power Up Unit

The controller's power up routine indicates that the processor is operating and that the controller has not had a catastrophic failure.

### Procedure

Attach a small power supply as battery:

- Power supply positive to "Battery +" on the controller
- Power supply negative to "Battery –" on the controller




Wiring Diagram

## Correct operation

- The unit performs a power up sequence:
- illuminates "Battery Status" LEDS Green→Yellow→Red
- illuminates only one "Battery Status" LED corresponding to the batteries state of charge
- If the unit has a meter, the meter should begin displaying each of the 3 values(Vbatt,Iarray,Iload)
- The "Charging" LED does NOT come on

## Failure

- The unit showed no signs of life
    - Damaged processor,
    - Damaged power supply
    - other failure
- Some/All LEDs illuminated, but no sequence
    - damaged processor
- An LED in the start up sequence did not illuminate
    - Bad or incorrectly mounted LED
    - damaged processor pin

- An LED on the Meter did not illuminate during a reading
  - Bad or incorrectly mounted LED
  - Bad meter connection
  - Damaged LCD driver

## 3. Self-Test Routine (Meter Option Only)

The self-test routine is special software run by the processor to check internal circuits for correct operation. This step is for units with the digital meter only. Go to step 4 if your unit does not have a meter.

### Procedure

Same wiring as step 2
Press and hold the disconnect button for approximately 4-5 seconds.

### Correct Operation

**The unit begins the self-test routine:**

| Item Displayed | Notes |
|---|---|
| 8.8.8 | Should display on the meter after 4-5sec and remain until the button is release |
| 12u / 24u / 48u | System voltage |
| 15A / 30A | Controller current rating |
| r1.X | Code revision number where "X" is a number |
| - - - | Indicates that no errors were detected |
| 25c | Ambient temperature at the controller |
| | |
| | |
| | |
| S-X | Battery select switch position (X=1,2,or 3) |
| | |
| End | Self test is complete |
| End - - - End | Sequences until disconnect button is pushed |

Notes:
1. Items in gray may not be displayed if probe or sense lines not connected
2. You may perform the test several times until you are certain you view all the information. To hasten the process, pushing the disconnect button during the self-test will immediately advance to the next displayed value

### Failure

- It gets about halfway through the test, then the controller resets!
  - check if there is something shorting the load +/- terminals of the controller.

- During the self-test routine, it displays an error code(s) "EXX" where XX is a number.
  - Refer to *table 1* below to troubleshoot any errors found.

## *Table 1. Error Summary of Self-Test*

| Error | Description | Possible Causes | Solutions | Notes |
|---|---|---|---|---|
| E01 | Battery Switch | Battery switch in empty 4th position, in between positons, or switch damaged | Use a screwdriver to ensure that one of the 3 battery types is selected. The switch should click into place | |
| E03 | Reference or Regulator | Reference diode or 5V regulator damaged/out of calibaration | Not a user serviceable failure | May cause a variety of other errors and failures |
| E04 | Array Side | Damaged Input MOSFETS<br><br>Processor A/D channel damaged<br><br>Array shunt circuit damaged | Refer to step 4 to confirm failure<br><br>Not a user serviceable failure<br><br>Not a user serviceable failure | |
| E07 | Load MOSFETs | Load MOSFETs shorted<br><br>Load Gate drive damaged<br><br>Load +/- jumpered together | Replace Load MOSFETS<br><br>Not a user serviceable failure<br><br>Check for debris or other objects shorting the load terminals | No LVD functionality<br><br>No load over-current protection |
| E08 | Load Current Zerot | Load current amplifier damaged<br><br>Load MOSFETs damaged<br><br>Load current circuit damaged | Not a user serviceable failure<br><br>Replace Load MOSFETs<br><br>Not a user serviceable failure | |
| E09 | Load MOSFET Open | Load MOSFETS open<br><br>Load gate drive damaged | Replace Load MOSFETS<br><br>Not a user serviceable failure | May reset the processor if short exists on load terminals |
| E10 | Internal temp probe open | Temp sensor damaged<br><br>Temp sensor cut/open | Replace temp sensor with a 2N3904 BJT transistor<br><br>Repair / Replace temp sensor with a 2N3904 BJT transistor<br><br>Not a user serviceable | No over-temperature protection |

| | | | | |
|---|---|---|---|---|
| | | Reference voltage too low | failure | |
| E11 | Internal temp probe shorted | Temp sensor damaged<br><br>Temp sensor shorted | Replace temp sensor with a 2N3904 BJT transistor<br><br>Inspect for debris, find and fix short | |
| E12 | Remote temp probe out of range | Temp sensor leads shorted<br><br>Temp sensor leads damaged<br><br>Reference voltage too low | Remove remote temperature probe, inspect for pinched cable, re-test without probe connected<br><br>Replace probe<br><br>Not a user serviceable failure | Defaults to on-board temperature sensor. Can not detect open remote temp probe, but "rP" will not be listed in self-test if probe not found.<br><br>If you do not have a probe attached and still get this error, check the connection point on the board where the probe would be soldered for a short. Else, the reference is probably bad. |
| E13 | Sense detect | Long battery leads cause excessive drop<br><br>The "Sense – " terminal is not connected | Minimize length of cables from battery to controller, Maximize cable gauge<br><br>Be sure both battery sense lines are securely attached and that they are not damaged | |

## 4. Check PV / Battery MOSFETs

The input MOSFET power transistors allow the controller to switch the power from the array to the battery/load.

### Procedure

Attach a small Ah battery:

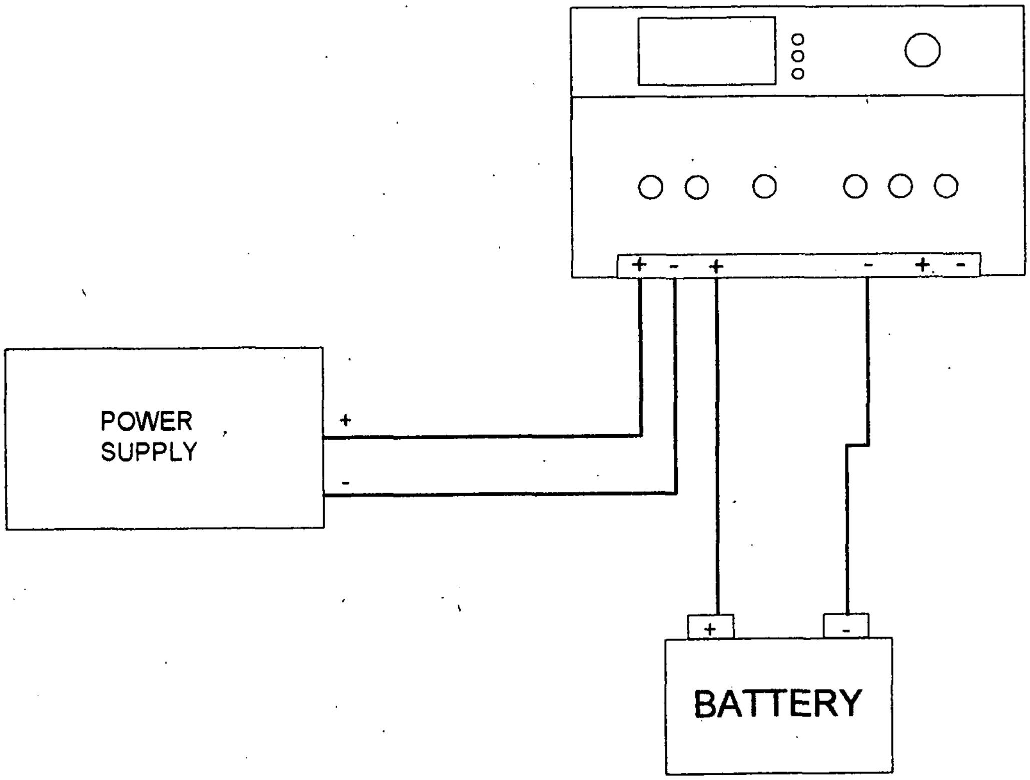
- Battery positive terminal to "Battery +" on the controller

- Battery negative terminal to "Battery –" on the controller

Note the status of the "Charging" LED
Adjust power supply to ~16V, set current limit to ~1A
Turn off power supply
Attach the power supply

- Power supply positive lead to "Solar +" on the controller
- Power supply negative lead to "Solar –" on the controller

Turn on power supply
Measure the "Array +/-" voltage
Measure the "Battery +/-" voltage




Wiring Diagram

## Correct Operation

- Before the power supply is attached, the "Charging" LED should be off
- After the power supply is attached and turned on, the "Charging" LED should be illuminated
- If the battery is not fully charged(i.e. below the regulation voltage), the measured Array and Battery voltages should be the same value (+/- 0.2V)

### Failure

- The "Charging" LED illuminates as soon as the battery is attached, without a power supply attached
  - MOSFETS may be damaged in a "shorted" state
- The "Charging" LED never illuminates after the power supply is attached
  - MOSFETS may be damaged in an "open" state
  - Damaged gate drive
- The measured array voltage is greater than the measured battery voltage
  - MOSFETS may be damaged in an "open" state or running linear
  - Damaged gate drive

## 5. Battery Removal Protection

Battery removal protection will shut down the controller in the event that the battery is removed while the Array is still connected. This protects any loads connected to the controller from the high voltage of the PV array.

### Procedure

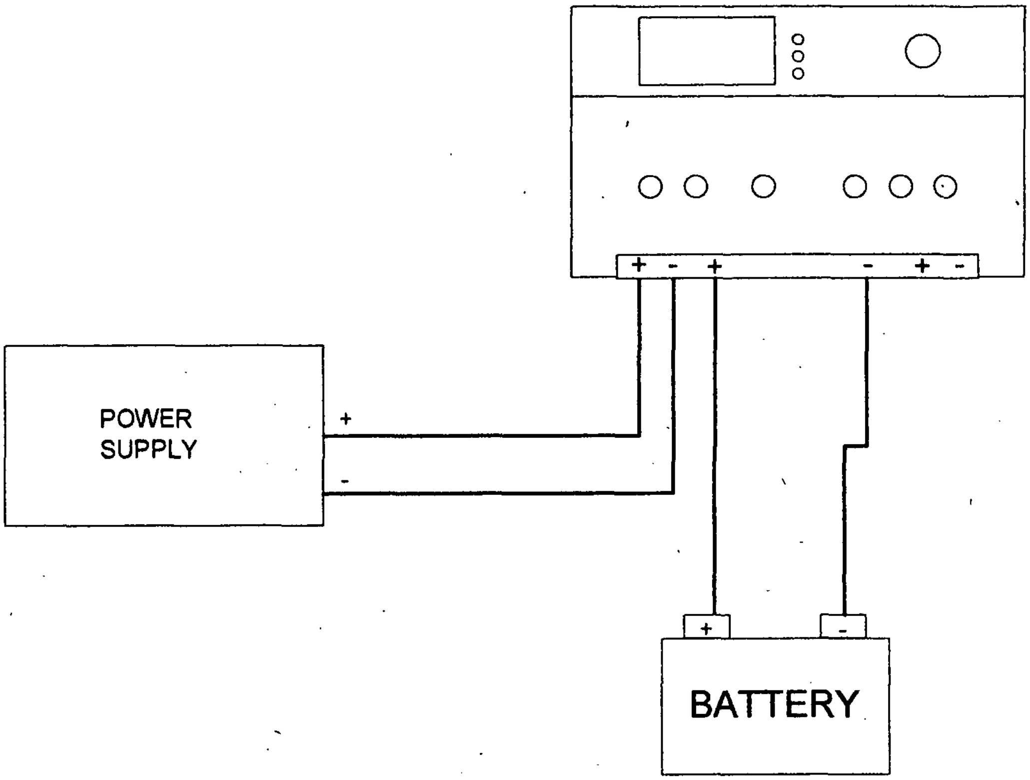
Attach a small Ah battery:

- Battery positive terminal to "Battery +" on the controller
- Battery negative terminal to "Battery –" on the controller

Adjust power supply to ~16V, set current limit to ~1A
Turn off power supply
Attach the power supply or PV panel:

- Power supply positive lead to "Solar +" on the controller
- Power supply negative lead to "Solar –" on the controller

Turn on power supply
Remove one of the battery leads (positive or negative)




Wiring Diagram

### Correct Operation

- When the battery lead is disconnected, the controller shuts down immediately.(All LEDS turn off)

### Failure

- When the battery lead is disconnected, the controller still operates (LEDS still illuminated)

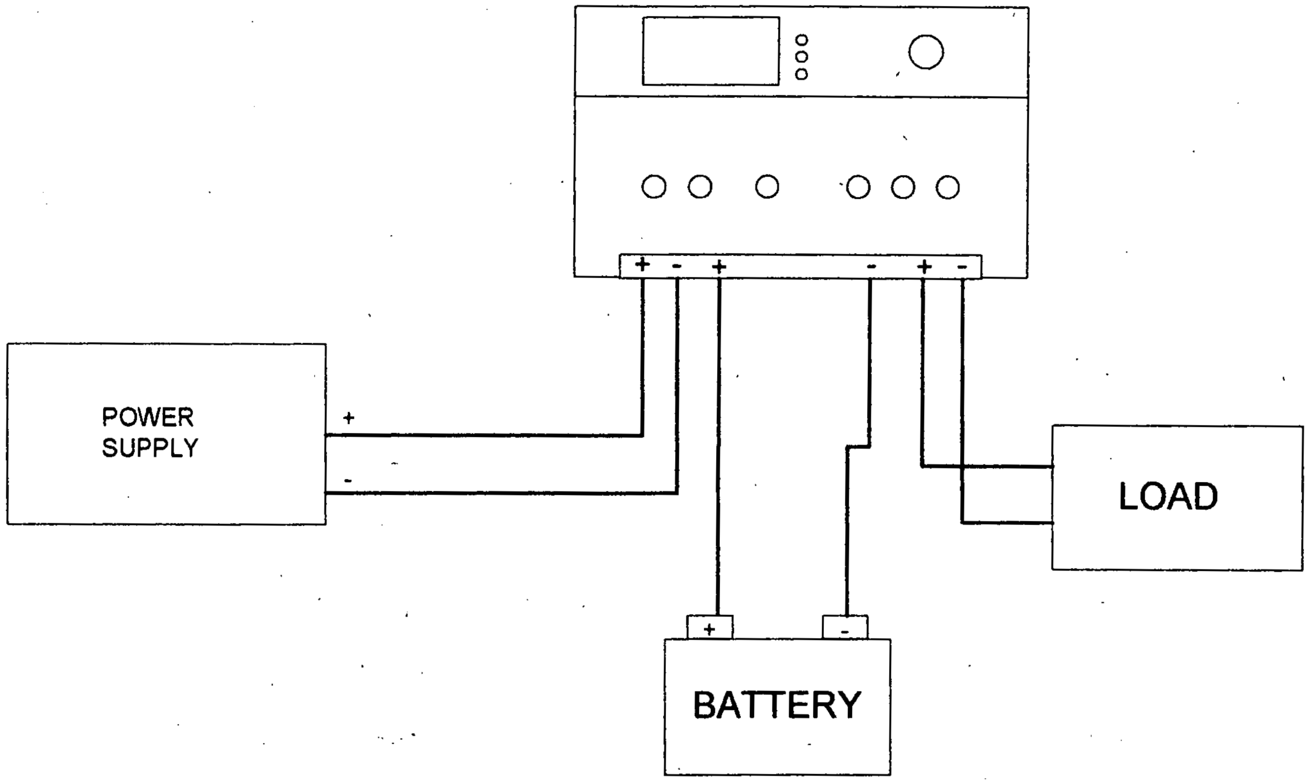
## 6. Putting It All Together

This last step will check the overall function of the controller, and provides one final check that everything is working properly

### Procedure

1. Wire a small load to the load terminals of the controller
2. Attach a small Ah battery:
   - Battery positive terminal to "Battery +" on the controller
   - Battery negative terminal to "Battery –" on the controller

3. Watch start-up sequence and observe when the load turns on.
4. Adjust power supply to ~16V, set current limit to ~1A
5. Turn off power supply
6. Attach the power supply
7. Power supply positive lead to "Solar +" on the controller
8. Power supply negative lead to "Solar –" on the controller
9. Wire a small load to the load terminals of the controller
10. Turn on the powersupply




Wiring Diagram

## Testing Operation

- The load turns on AFTER the controller finishes the start-up sequence. If the load turns on before the start-up sequence, the load MOSFETs may be damaged.
- The "Charging" LED is illuminated.
- The Load turns off when the disconnect button is pressed once. (meter units will display "OFF" for load current reading)
- The Load turns on again when the button is pressed a second time.
- When the disconnect button is pressed and held for 3 seconds, then released, the load turns off and the "Charging" LED turns off – disconnecting both Load and Array. (meter units will display "OFF" for both Load and Array current)

- Press the button and release once more and both the PV and Load are reconnected.

## Appendix C - Routine Operations Checklist

| Groundwater Plume Treatment System Routine Operations Checklist | | | | | |
|---|---|---|---|---|---|
| **Checked by:** | | | **Date:** | | |
| **Mound Plume Treatment System** | | | | | |
| **Check Valve Positions** | | **Check Flowmeter** | | **Flow at Discharge Point?** | |
| **Flow Rate (gpm)** | | **Normal Range: 0-4 gpm** | | | |
| **Depth to Water in Treatment cells (feet, measured from opening)** | **West Cell** | | **East Cell** | | **Normal Range: 4-4.5 feet** |
| **Is Treatment cell Crusted Over?** | | **Gravel /Iron Layer Raked?** | | | |
| **Observations/Comments:** | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **East Trenches Plume Treatment System** | | | | | |
| **Check Valve Positions** | | **Check Flowmeter** | | **Flow at Discharge Point?** | |
| **Flow Rate (gpm)** | | **Normal Range: 0.02-10 gpm** | | | |
| **Depth to Water in Treatment cells (feet, measured from opening)** | **West Cell** | | **East Cell** | | **Normal Range: 5-5.5 feet** |
| **Is Treatment cell Crusted Over?** | | **Gravel /Iron Layer Raked?** | | | |
| **Observations/Comments:** | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **Solar Ponds Plume Treatment System** | | | | | |
| **Check Valve Positions** | | **Check Flowmeter** | | **Check Seal on Vessels** | |
| **Flow Rate (gpm)** | | **Normal Range: 1-9 gpm** | | | |
| **Pump Switched On?** | | **Is the pump cycling on and off?** | | | |
| **Flow Into Cell?** | | **Check Panel Position** | | | |
| **Power system** | **Are there signs of overcharging or corrosion of the batteries?** | | | | |
| **In sunlight, is the green charging indicator light on?** | | | | | |
| **Battery type selector set to sealed?** | | **Display reading for battery status** | | | |
| **Display reading for solar amps** | | **Display reading for load amps** | | | |
| **Is the load or solar array disconnected?** | | **Is the red LED battery status light on?** | | | |
| **Record any error number(s) from diagnostic check here** | | **Record any disconnect or protection indicators here** | | | |
| **Observations/Comments:** | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

163

# Appendix D - Calculation of Necessary Depths and Volumes of Zero-Valent Iron and Iron/Pea Gravel Mixture

**Purpose:** To Determine Depths And Volumes For Media Replacement In The Mound Site Plume Treatment System (MSPTS) & East Trenches Plume Ground Water Treatment System (ETPTS).

**Assumptions:**

1) Assume that the iron volume change is negligible when added to the gravel.
2) Assume all measurements need to be made from the top of the treatment cell due to possible errors in the as-builts.
3) Assume that the wall thickness of each vessel is one inch.
4) Assume that both systems will have a six inch gravel/iron layers and need to maintain one foot of additional groundwater head on each bed.
5) Depth to water was estimated and might need to be adjusted.

**Calculations:**

1) The depth to each layer was based on an estimated depth to water from the lip of the opening for the treatment cell doors.
2) The volume of the gravel was calculated by calculating the cross-sectional area:

$$A = \pi r^2$$

Where,

A = Cross-Sectional Area (cubic feet)

r = Inside Radius of Vessel (feet)

3) Due to problems with the as-builts, the volume of the iron layer can no be determined until treatment cell dimensions are known.

I.

**Table D-1 Dimensions and Calculated Values for Zero Valent Iron Treatment cells**

| Parameter | East Trenches Treatment System (ft) | Mound Plume Treatment System (ft) |
|---|---|---|
| Outside Diameter (feet) | 11.50 | 9.83 |
| Inside Diameter (feet) | 11.33 | 9.67 |
| Inside Radius (feet) | 5.67 | 4.83 |
| Cross-Sectional Area (sq feet) | 100.9 | 73.4 |
| Depth to Water From Treatment cell Doors (feet) | 5 | 4.57 |
| Groundwater Head over Gravel Layer (feet) | 1 | 1 |
| Gravel Layer Thickness (feet) | 0.5 | 0.5 |
| Depth to Top of Iron from Treatment cell Doors (feet) | 6.5 | 6.07 |
| Depth to Top of Gravel from Treatment cell Doors (feet) | 6 | 5.57 |
| Volume of Gravel Layer (cubic feet) | 50.4 | 36.7 |
| Volume of Iron (cu ft) in Gravel/Iron Mixture | 5.60 | 4.08 |
| Drainage Layer Thickness (feet) | 0.9 | 1.0 |

## Appendix E – Zero-Valent Iron Specifications

| | |
|---|---|
| **Supplier:** | Connelly-GPM, Inc. |
| **Address:** | 3154 South California Avenue<br>Chicago, Illinois 60608-5176 |
| **Telephone Number:** | 773-247-7231 |
| **Fax Number:** | 773-247-7239 |
| **Website:** | www.Connelygpm.com |
| **Email Address:** | ConnellyGPM@aol.com |
| **Product Name:** | Iron Aggregate ETI CC-1004 |
| **Sieve Size:** | -8 +50 mesh, U.S. Screen Size |

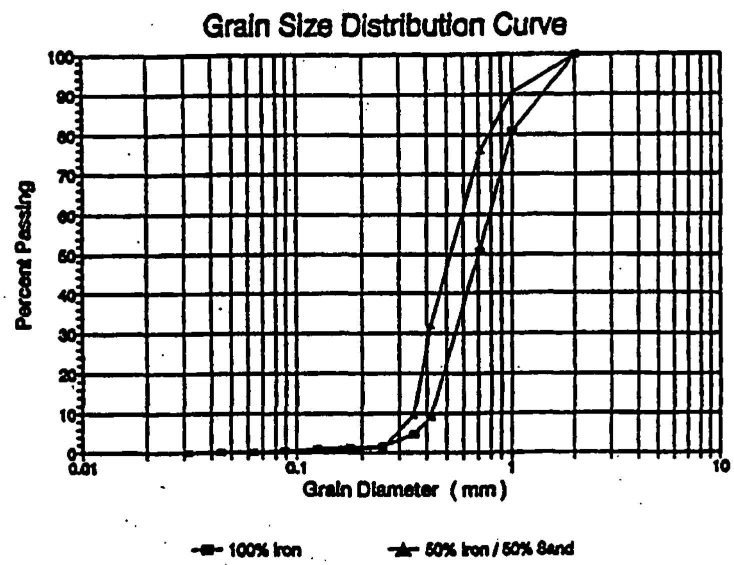
| | |
|---|---|
| **Alternate Supplier:** | Peerless Metal Powders & Abrasives |
| **Address:** | 124 S. Military Ave.<br>Detroit, MI 48209 |
| **Telephone Number:** | 313-841-5400 |
| **Fax Number:** | 313-841-0240 |
| **Product Name:** | GX-027 |
| **Sieve Size:** | -8 +50 mesh, U.S. Screen Size |

166

enviro metal technologies inc.

## Reactive Material Specifications

The reactive material to be placed in the treatment zone is a granular iron material. The iron has a grain size distribution of approximately -8 to +50 mesh US Std Sieve Size. The figure below shows the grain size distribution curves for a both a 100% iron and a 50% iron / 50% sand mixture. The iron has a field bulk density ranging from 140 to 160 lb/ft$^3$. It can be shipped to the site in a variety of containers including fiber superbags containing 3,000 lbs or by bulk in trucks. The choice of delivery method may be dependent on the preference of construction contractor selected. The only health and safety issues associated with this granular iron material is the iron dust particles. The appropriate dust masks and safety glasses/goggles are required. Material safety data sheets are available from the iron suppliers. Iron stored on site should be securely covered until required.




42 Arrow Road
Guelph, Ontario
Canada N1K 1S8
Tel (519) 824-0432
Fax (519) 763-2378

## Appendix F – Photographs of Media Replacement Activities

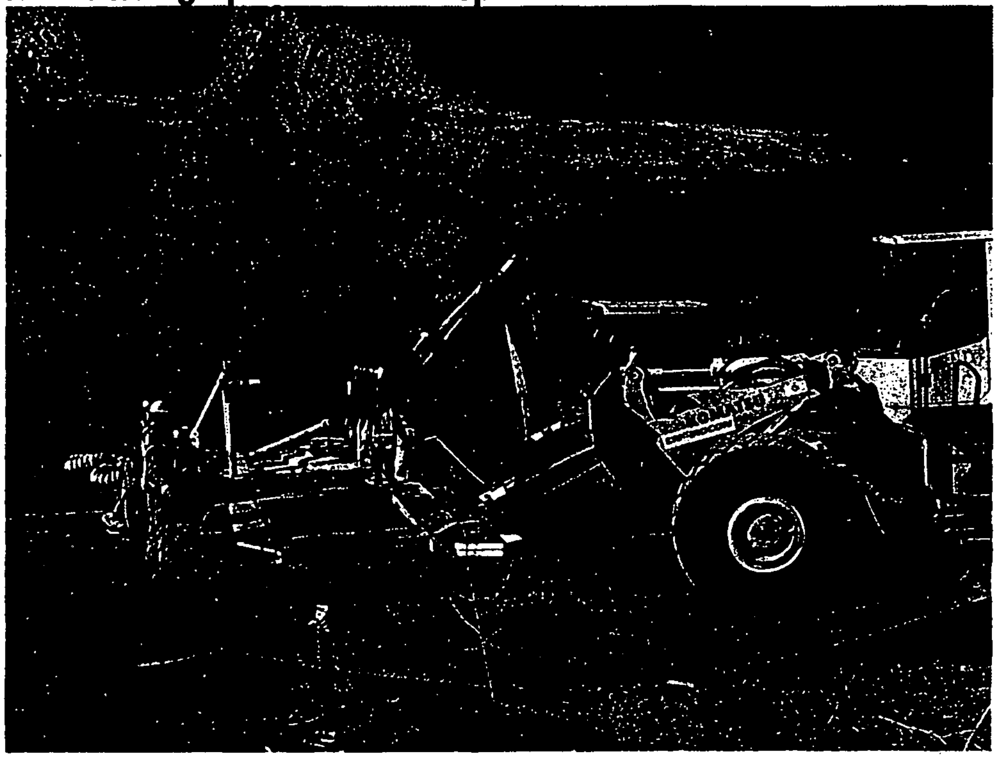


**Figure G-1 Excavation of Solidified Zero Valent Iron Bed Pieces After Breaking up Solidified Layer**

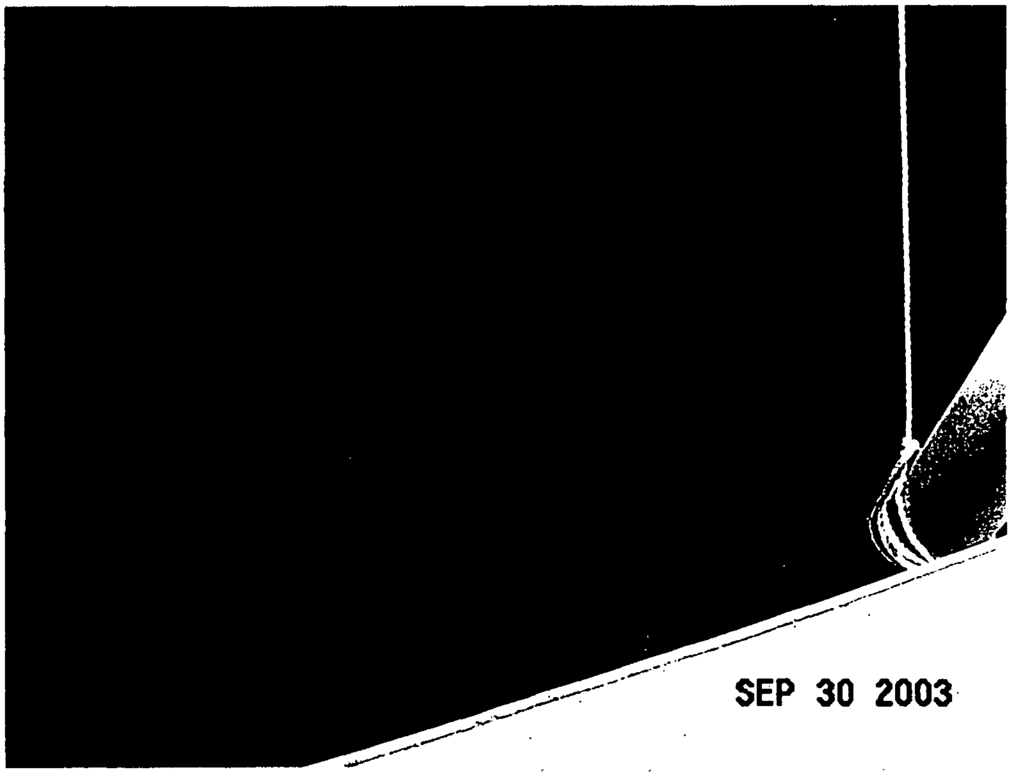



**Figure G-2 Removal of Solidified Zero Valent Iron Bed Using Vacuum Excavation Line**

**Figure G-3 Solidified Zero Valent Iron, (The loose material is iron from the lower portion of the bed that remained unconsolidated.)**

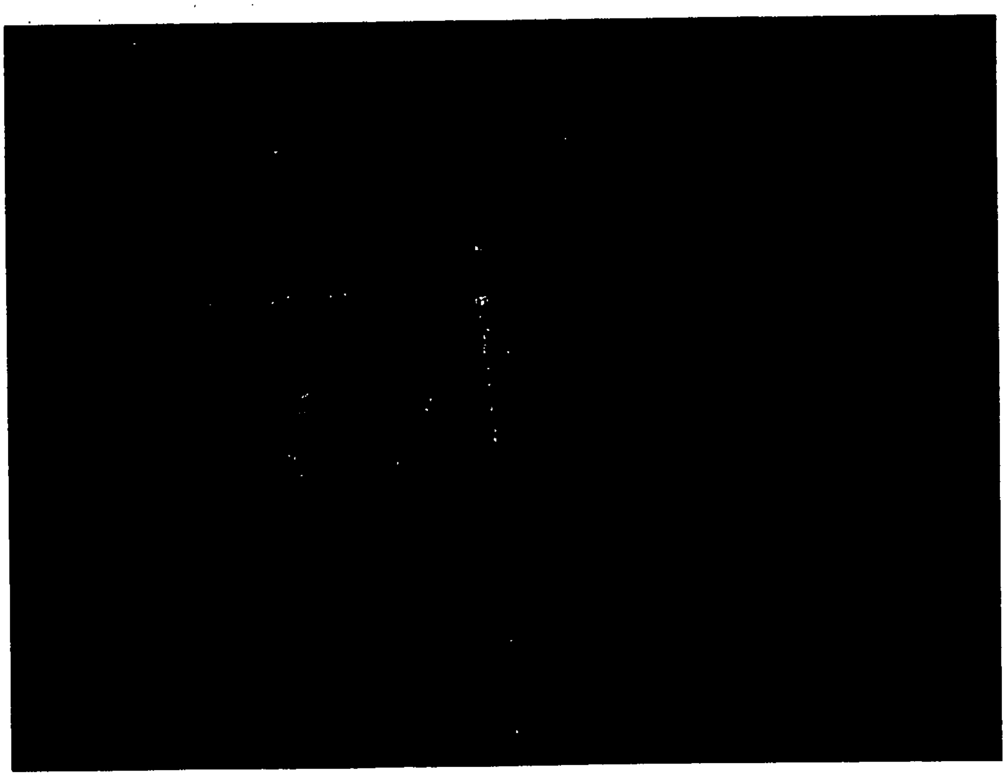


**Figure G-4 Figure Showing Drainage Piping at Treatment cell Bottom After Media Is Removed**

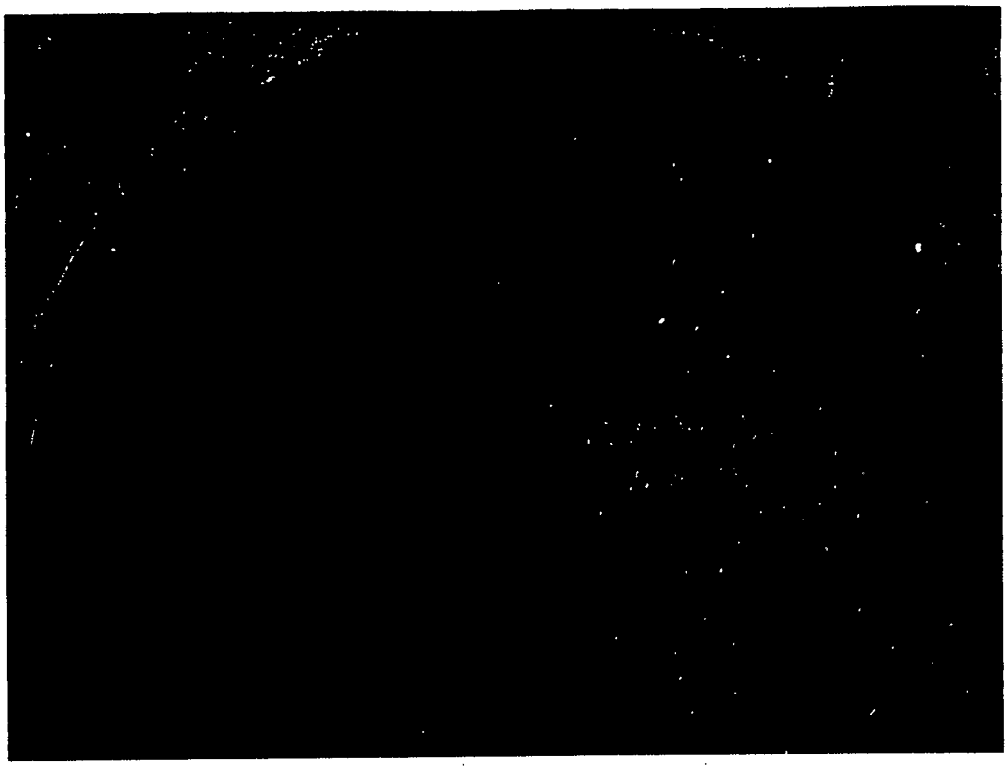


**Figure G-5 Filter Fabric Overlaying Pea Gravel in Drainage Layer at the Bottom of the Treatment cell**

**Figure G-6 Zero-Valent Iron Being Added to Treatment Cell**

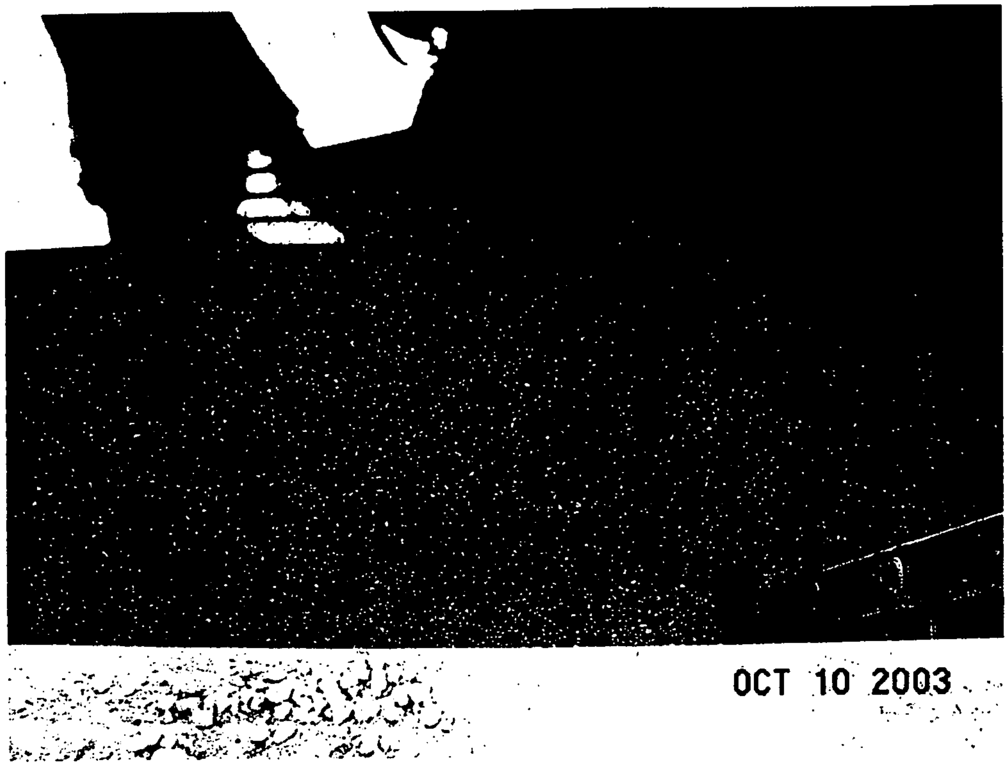



**Figure G-7 Top of Gravel/Zero-Valent Iron Layer After Completion of Media Replacement**

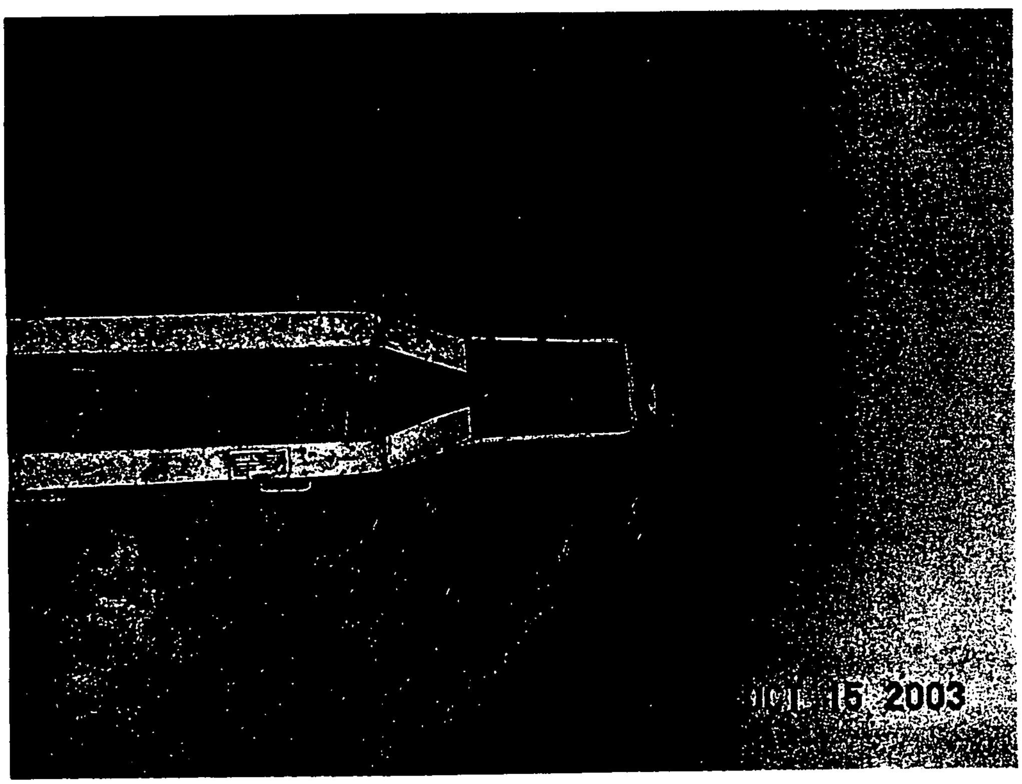


**Figure G-8 Flowmeter Flume**

## Appendix G - Maintenance Log Forms

| Maintenance Log for Mound Plume Treatment System | | Page |
|---|---|---|
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |

172

| Maintenance Log for East Trenches Treatment System | | Page |
|---|---|---|
| Date: ☐ | Routine Check | Repair |
| Work Performed By: | | |
| Description: | | |
| | | |
| | | |
| | | |
| | | |
| Date: ☐ | Routine Check | Repair |
| Work Performed By: | | |
| Description: | | |
| | | |
| | | |
| | | |
| | | |
| Date: ☐ | Routine Check | Repair |
| Work Performed By: | | |
| Description: | | |
| | | |
| | | |
| | | |
| | | |
| Date: ☐ | Routine Check | Repair |
| Work Performed By: | | |
| Description: | | |
| | | |
| | | |
| | | |
| | | |

| **Maintenance Log for Solar Ponds Plume Treatment System** | | **Page** |
|---|---|---|
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |
| **Date:** ☐ | **Routine Check** | **Repair** |
| **Work Performed By:** | | |
| **Description:** | | |
| | | |
| | | |
| | | |
| | | |

174/174